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PROCEEDINGS

OF

THE AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

FOR THE FORTY-THIRD MEETING

HELD AT

BROOKLYN, N. Y.

AUGUST, 1894

SALEM:
PUBLISHED BY THE PERMANENT SECRETARY.
MARCH, 1895.

BOSTON MEDICAL
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EDITED BY

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CATALOGUED
JUL 1 1903
E. H. B.

PRINTED BY GEO. A. AYLWARD,
The Salem Press.
SALEM, MASS.
1895.

BOSTON MEDICAL
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By a strange mistake a partial list of the Local Committee for the Brooklyn Meeting was printed in the Volume of Proceedings of the Madison Meeting, in place of the Local Committee for the Madison Meeting as follows:—

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FOR THE

MEETING OF 1895.

Past Presidents.—JAMES D. DANA of New Haven; JAMES HALL of Albany; B. A. GOULD of Cambridge; SIMON NEWCOMB of Washington; O. C. MARSH of New Haven; GEORGE F. BARKER of Philadelphia; GEORGE J. BRUSH of New Haven; J. W. DAWSON of Montreal; C. A. YOUNG of Princeton; J. P. LESLEY of Philadelphia; H. A. NEWTON of New Haven; EDWARD S. MORSE of Salem; S. P. LANGLEY of Washington; J. W. POWELL of Washington: T. C. MENDENHALL of Washington; GEORGE L. GOODALE of Cambridge; ALBERT B. PRESCOTT of Ann Arbor; JOSEPH LECONTE of Berkeley; WILLIAM HARKNESS of Washington; D. G. BRINTON of Media.

Vice Presidents of the Last Meeting.—EDGAR FRISBY of Washington; WM. A. ROGERS of Waterville; T. H. NORTON of Cincinnati; MANSFIELD MERRIMAN of South Bethlehem; SAMUEL CALVIN of Iowa City; J. A. LINTNER of Albany; C. E. BESSEY of Lincoln; FRANZ BOAS of New York; HENRY FARQUHAR of Washington.

Officers of the Forty-fourth Meeting.—E. W. MORLEY of Cleveland; E. S. HOLDEN of Mt. Hamilton; W. LECONTE STEVENS of Troy; WILLIAM MCMURTRIE of Brooklyn; WM. KENT of Passaic; JED. HOTCHKISS of Staunton; D. S. JORDAN of Palo Alto; J. C. ARTHUR of Lafayette; F. H. CUSHING of Washington; B. E. FERNOW of Washington; F. W. PUTNAM of Cambridge; JAS. LEWIS HOWE of Lexington; C. R. BARNES of Madison; E. H. MOORE of Chicago; E. MERRITT of Ithaca; W. P. MASON of Troy; H. S. JACOBY of Ithaca; J. PERRIN SMITH of Palo Alto; S. A. FORBES of Champaign; B. T. GALLOWAY of Washington; ANITA NEWCOMB MCGEE of Washington; E. A. ROSS of Palo Alto; R. S. WOODWARD of New York.

From the Association at Large.—To hold over until successors are elected. A fellow elected from each section.—R. S. WOODWARD of New York (**A**); W. LECONTE STEVENS of Troy (**B**); ALFRED SPRINGER of Cincinnati (**C**); ARTHUR BEARDSLEY of Swarthmore (**D**); G. G. HUBBARD of Washington (**E**); W. H. DALL of Washington (**F**); BYRON D. HALSTEAD of New Brunswick (**G**); W J MCGEE of Washington (**H**); GEORGE H. PERKINS of Burlington (**I**).

MEETINGS AND OFFICERS OF THE AMERICAN ASSOCIATION OF GEOLOGISTS AND NATURALISTS.

MEETING.	DATE.	PLACE.	CHAIRMAN.	SECRETARY.	ASSIS'T SEC'Y.	TREASURER.
1st	April 2, 1840,	Philadelphia,	Edward Hitchcock,*	L. C. Beck,*		
2d	April 5, 1841,	Philadelphia,	Benjamin Silliman,*	L. C. Beck,*	B. Silliman, jr.,* C. B. Trego,*	
3d	April 25, 1842,	Boston,	S. G. Morton,*	C. T. Jackson,*	J. D. Whitney, M. B. Williams,*	
4th	April 26, 1843,	Albany,	Henry D. Rogers,*	B. Silliman, jr.,*		John Locke.*
5th	May 8, 1844,	Washington,	John Locke,*	B. Silliman, jr.,* O. P. Hubbard,		Douglas Houghton.*
6th	April 30, 1845,	New Haven,	Wm. B. Rogers,*	B. Silliman, jr.,* J. Lawrence Smith,*		Douglas Houghton.*
7th	Sept. 2, 1846,	New York,	C. T. Jackson,*	B. Silliman, jr.,*		E. C. Herrick.*
8th	Sept. 20, 1847,	Boston,	Wm. B. Rogers,†*	Jeffries Wyman,*		B. Silliman, jr.*

* Deceased.

† Professor ROGERS, as chairman of this last meeting, called the first meeting of the new Association to order and presided until it was fully organized by the adoption of a constitution. As he was thus the first presiding officer of the new Association, it was directed at the Hartford meeting that his name be placed at the head of the Past Presidents of the American Association for the Advancement of Science.

MEETINGS.	PLACE.	DATE.	MEMBERS IN ATTENDANCE.	NUMBER OF MEMBERS.
1.	Philadelphia	Sept. 20, 1848	?	461
2.	Cambridge	Aug. 14, 1849	?	540
3.	Charleston	Mar. 12, 1850	?	622
4.	New Haven	Aug. 19, 1850	?	704
5.	Cincinnati	May 5, 1851	87	800
6.	Albany	Aug. 19. 1851	194	769
7.	Cleveland	July 28, 1853	?	940
8.	Washington	April 26, 1854	168	1004
9.	Providence	Aug. 15, 1855	166	605
10.	2nd Albany	Aug. 20, 1856	381	722
11.	Montreal	Aug. 12, 1857	351	946
12.	Baltimore	April 28, 1858	190	962
13.	Springfield	Aug. 3, 1859	190	862
14.	Newport	Aug. 1, 1860	135	644
15.	Buffalo	Aug. 15, 1866	79	687
16.	Burlington	Aug. 21. 1867	73	415
17.	Chicago	Aug. 5, 1868	259	686
18.	Salem	Aug. 18, 1869	244	511
19.	Troy	Aug. 17, 1870	188	536
20.	Indianapolis	Aug. 16, 1871	196	668
21.	Dubuque	Aug. 15, 1871	164	610
22.	Portland	Aug. 20, 1873	195	670
23.	Hartford	Aug. 12, 1874	224	722
24.	Detroit	Aug. 11, 1875	165	807
25.	2nd Buffalo	Aug. 23, 1876	215	867
26.	Nashville	Aug. 29, 1877	173	953
27.	St. Louis	Aug. 21, 1878	134	962
28.	Saratoga	Aug. 27, 1879	256	1030
29.	Boston	Aug. 25, 1880	997	1555
30.	2nd Cincinnati	Aug. 17, 1881	500	1699
31.	2nd Montreal	Aug. 23, 1882	937	1922
32.	Minneapolis	Aug. 15, 1883	328	2033
33.	2nd Philadelphia	Sept. 3, 1884	1261*	1981
34.	Ann Arbor	Aug. 26, 1885	364	1956
35.	3d Buffalo	Aug. 18, 1886	445	1886
36.	New York	Aug. 10, 1887	729	1956
37.	2nd Cleveland	Aug. 14, 1888	342	1964
38.	Toronto	Aug. 26, 1889	424	1952
39.	2d Indianapolis	Aug. 19. 1890	364	1944
40.	2d Washington	Aug. 19, 1891	653†	2054
41.	Rochester	Aug. 17, 1892	456	2037
42.	Madison	Aug. 17, 1893	290	1939
43.	Brooklyn	Aug. 15, 1894	488	1802

*Including members of the British Association and other foreign guests.
†Including twenty-four Foreign Honorary members for the meeting.

OFFICERS OF THE MEETINGS OF THE ASSOCIATION.

[The number before the name is that of the meeting; the year of the meeting follows the name; the asterisk after a name indicates that the member is deceased.]

PRESIDENTS.

1. { WM. B. ROGERS,* 1848. / W. C. REDFIELD,* 1848.
2. JOSEPH HENRY,* 1849.
3, 4, 5. A. D. BACHE,* March meeting, 1850, in absence of JOSEPH HENRY.* August meeting, 1850. May meeting, 1851.
6. LOUIS AGASSIZ,* August meeting, 1851.
(No meeting in 1852).
7. BENJAMIN PIERCE,* 1853.
8. JAMES D. DANA, 1854.
9. JOHN TORREY,* 1855.
10. JAMES HALL, 1856.
11, 12. ALEXIS CASWELL,* 1857, in place of J. W. BAILEY,* deceased. 1858, in absence of JEFFRIES WYMAN.*
13. STEPHEN ALEXANDER,* 1859.
14. ISAAC LEA,* 1860.
(No meetings for 1861–65).
15. F. A. P. BARNARD,* 1866.
16. J. S. NEWBERRY,* 1867.
17. B. A. GOULD, 1868.
18. J. W. FOSTER,* 1869.
19. T. STERRY HUNT,* 1870, in the absence of WM. CHAUVENET.*
20. ASA GRAY,* 1871.
21. J. LAWRENCE SMITH,* 1872.
22. JOSEPH LOVERING,* 1873.
23. J. L. LECONTE,* 1874.
24. J. E. HILGARD,* 1875.
25. WILLIAM B. ROGERS,* 1876.
26. SIMON NEWCOMB, 1877.
27. O. C. MARSH, 1878.
28. G. F. BARKER, 1879.
29. LEWIS H. MORGAN,* 1880.
30. G. J. BRUSH, 1881.
31. J. W. DAWSON, 1882.
32. C. A. YOUNG, 1883.
33. J. P. LESLEY, 1884.
34. H. A. NEWTON, 1885.
35. EDWARD S. MORSE, 1886.
36. S. P. LANGLEY, 1887.
37. J. W. POWELL, 1888.
38. T. C. MENDENHALL, 1889.
39. G. LINCOLN GOODALE, 1890.
40. ALBERT B. PRESCOTT, 1891.
41. JOSEPH LECONTE, 1892.
42. WILLIAM HARKNESS, 1893.
43. DANIEL G. BRINTON, 1894.
44. E. W. MORLEY, 1895.

VICE-PRESIDENTS.

There were no vice-presidents until the 11th meeting when there was a single vice-president for each meeting. At the 24th meeting the Association met in Sections A and B, each presided over by a vice-president. At the 31st meeting nine sections were organized, each with a vice-presidents as its presiding officer. In 1886, Section G (Microscopy) was given up. In 1892, the Section of Botany was organized as Section G.

1857–1874.

11. ALEXIS CASWELL,* 1857, acted as President.
12. JOHN E. HOLBROOK,* 1858, not present.
13. EDWARD HITCHCOCK,* 1859.
14. B. A. GOULD, 1860.
15. A. A. GOULD,*1866, in absence of R. W. GIBBES.
16. WOLCOTT GIBBS, 1867.
17. CHARLES WHITTLESEY,* 1868.
18. OGDEN N. ROOD, 1869.
19. T. STERRY HUNT,* 1870, acted as President.
20. G. F. BARKER, 1871.
21. ALEXANDER WINCHELL,* 1872.
22. A. H. WORTHEN,* 1873, not present.
23. C. S. LYMAN,* 1874.

1875–1881.

Section A.—Mathematics, Physics and Chemistry.

24. H. A. NEWTON, 1875.
25. C. A. YOUNG, 1876.
26. R. H. THURSTON, 1877, in the absence of E. C. PICKERING.
27. R. H. THURSTON, 1878.
28. S. P. LANGLEY, 1879.
29. ASAPH HALL, 1880.
30. WILLIAM HARKNESS, 1881, in the absence of A. M. MAYER.

Section B.—Natural History.

24. J. W. DAWSON, 1875.
25. EDWARD S. MORSE, 1876.
26. O. C. MARSH, 1877.
27. AUG. R. GROTE, 1878.
28. J. W. POWELL, 1879.
29. ALEXANDER AGASSIZ, 1880.
30. EDWARD T. COX, 1881, in the absence of GEORGE ENGELMANN.*

CHAIRMEN OF SUBSECTIONS, 1875–1881.

Subsection of Chemistry.

24. S. W. JOHNSON, 1875.
25. G. F. BARKER, 1876.
26. N. T. LUPTON, 1877.
27. F. W. CLARKE, 1878.
28. F. W. CLARKE, 1879, in the absence of IRA REMSEN.
29. J. M. ORDWAY, 1880.
30. G. C. CALDWELL, 1881, in the absence of W. R. NICHOLS.*

Subsection of Microscopy.

25. R. H. WARD, 1876.
26. R. H. WARD, 1877.
27. R. H. WARD, 1878, in the absence of G. S. BLACKIE.*
28. E. W. MORLEY, 1879.
29. S. A. LATTIMORE, 1880.
30. A. B. HERVEY, 1881.

Subsection of Anthropology.

24. LEWIS H. MORGAN,* 1875.
25. LEWIS H. MORGAN,* 1876.
26. DANIEL WILSON,* 1877, not present
27. United with Section B.
28. DANIEL WILSON,* 1879.
29. J W. POWELL, 1880.
30. GARRICK MALLERY,* 1881.

Subsection of Entomology.

30. J. G. MORRIS, 1881.

VICE PRESIDENTS OF SECTIONS, 1882–

Section A.—Mathematics and Astronomy.

31. W. A. ROGERS, 1882, in the absence of WILLIAM HARKNESS.
32. W. A. ROGERS, 1883.
33. H. T. EDDY, 1884,
34. WILLIAM HARKNESS, 1885, in the absence of J. M. VAN VLECK.
35. J. W. GIBBS, 1886.
36. J. R. EASTMAN, 1887, in place of W. FERREL,* resigned.
37. ORMOND STONE, 1888.
38. R. S. WOODWARD, 1889.
39. S. C. CHANDLER, 1890.
40. E. W. HYDE, 1891.
41. J. R. EASTMAN, 1892.
42. C. L. DOOLITTLE, 1893.
43. { G. C. COMSTOCK, 1894. / EDGAR FRISBY, 1894.
44. E. S. HOLDEN, 1895.

Section B.—Physics.

31. T. C. MENDENHALL, 1882.
32. H. A. ROWLAND, 1883.
33. J. TROWBRIDGE, 1884.
34. S. P. LANGLEY, 1885, in place of C. F. BRACKETT, resigned.
35. C. F. BRACKETT, 1886.
36. W. A. ANTHONY, 1887.
37. A. A. MICHELSON, 1888.
38. H. S. CARHART, 1889.
39. CLEVELAND ABBE, 1890.
40. F. E. NIPHER, 1891.
41. B. F. THOMAS, 1892.
42. E. L. NICHOLS, 1893.
43. WM. A. ROGERS, 1894.
44. W. LECONTE STEVENS, 1895.

Section C.—Chemistry.

31. H. C. BOLTON, 1882.
32. E. W. MORLEY, 1883.
33. J. W. LANGLEY, 1884.
34. N. T. LUPTON, 1885, in absence of W. R. NICHOLS.*
35. H. W. WILEY, 1886.
36. A. B. PRESCOTT, 1887.
37. C. E. MUNROE, 1888.
38. W. L. DUDLEY, 1889.
39. R. B. WARDER, 1890.
40. R. C. KEDZIE, 1891.
41. ALFRED SPRINGER, 1892.
42. EDWARD HART, 1893.
43. T. H. NORTON, 1894.
44. WM. MCMURTRIE, 1895.

Section D.—Mechanical Science and Engineering.

31. W. P. TROWBRIDGE,* 1882.
32. DE VOLSON WOOD, 1883, absent, but place was not filled.
33. R. H. THURSTON, 1884.
34. J. BURKITT WEBB, 1885.
35. O. CHANUTE, 1886.
36. E. B. COXE, 1887.
37. C. J. H. WOODBURY, 1888.
38. JAMES E. DENTON, 1889; 1890, in place of ARTHUR BEARDSLEY unavoidably absent.
39. THOMAS GRAY, 1891.
40. J. B. JOHNSON, 1892.
41. S. W. ROBINSON, 1893.
42. MANSFIELD MERRIMAN, 1894.
43. WILLIAM KENT, 1895.

VICE PRESIDENTS OF SECTIONS, CONTINUED.

Section E.—Geology and Geography.

31. E. T. COX, 1882.
32. C. H. HITCHCOCK, 1883.
33. N. H. WINCHELL, 1884.
34. EDWARD ORTON, 1885.
35. T. C. CHAMBERLIN, 1886.
36. G. K. GILBERT, 1887.
37. GEORGE H. COOK,* 1888.
38. CHARLES A. WHITE, 1889.
39. JOHN C. BRANNER, 1890.
40. J. J. STEVENSON, 1891.
41. H. S. WILLIAMS, 1892.
42. CHARLES D. WALCOTT, 1893.
43. SAMUEL CALVIN, 1894.
44. JED. HOTCHKISS, 1895.

Section F.—Biology.

31. W. H. DALL, 1882.
32. W. J. BEAL, 1883.
33. E. D. COPE, 1884.
34. T. J. BURRILL, 1885, in the absence of B. G. WILDER.
35. H. P. BOWDITCH, 1886.
36. W. G. FARLOW, 1887.
37. C. V. RILEY, 1888.
38. GEORGE L. GOODALE, 1889.
39. C. S. MINOT, 1890.
40. J. M. COULTER, 1891.
41. S. H. GAGE, 1892.

Section F.— Zoölogy.

42. HENRY F. OSBORN, 1893.
43. J. A. LINTNER, 1894, in place of S. H. SCUDDER, resigned.
44. D. S. JORDAN, 1895.

Section G.—Microscopy.

31. A. H. TUTTLE, 1882.
32. J. D. COX, 1883.
33. T. G. WORMLEY, 1884.
34. S. H. GAGE, 1885.
(Section united with F in 1886.)

Section G.—Botany.

42. CHARLES E. BESSEY, 1893.
43. { L. M. UNDERWOOD, 1894.
{ C. E. BESSEY, 1894.
44. J. C. ARTHUR, 1895.

Section H.—Anthropology.

31. ALEXANDER WINCHELL,* 1882.
32. OTIS T. MASON, 1883.
33. EDWARD S. MORSE, 1884.
34. J. OWEN DORSEY, 1885, in absence of W. H. DALL.
35. HORATIO HALE, 1886.
36. D. G. BRINTON, 1887.
37. CHARLES C. ABBOTT, 1888.
38. GARRICK MALLERY,* 1889.
39. FRANK BAKER, 1890.
40. JOSEPH JASTROW, 1891.
41. W. H. HOLMES, 1892.
42. J. OWEN DORSEY, 1893.
43. FRANZ BOAS, 1894.
44. F. H. CUSHING, 1895.

Section I.—Economic Science and Statistics.

31. E. B. ELLIOTT,* 1882.
32. FRANKLIN B. HOUGH,* 1883.
33. JOHN EATON, 1884.
34. EDWARD ATKINSON, 1885.
35. JOSEPH CUMMINGS,* 1886.
36. H. E. ALVORD, 1887.
37. CHARLES W. SMILEY, 1888.
38. CHARLES S. HILL, 1889.
39. J. RICHARDS DODGE, 1890.
40. EDMUND J. JAMES, 1891.
41. LESTER F. WARD, 1892, in place of S. DANA HORTON, resigned.
42. WILLIAM H. BREWER, 1893.
43. HENRY FARQUHAR, 1894.
44. B. E. FERNOW, 1895.

SECRETARIES.

General Secretaries, 1848–

1. WALTER R. JOHNSON,* 1848.
2. EBEN N. HORSFORD,* 1849, in the absence of JEFFRIES WYMAN.*
3. L. R. GIBBS, 1850, in absence of E. C. HERRICK.*
4. E. C. HERRICK,* 1850.
5. WILLIAM B. ROGERS,* 1851, in absence of E. C. HERRICK.*
6. WILLIAM B. ROGERS,* 1851.
7. S. ST. JOHN,* 1853, in absence of J. D. DANA.
8. J. LAWRENCE SMITH,* 1854.
9. WOLCOTT GIBBS, 1855.
10. B. A. GOULD, 1856.
11. JOHN LECONTE,* 1857.
12. W. M. GILLESPIE,* 1858, in absence of WM. CHAUVENET.
13. WILLIAM CHAUVENET,* 1859.
14. JOSEPH LECONTE, 1860.
15. ELIAS LOOMIS,* 1866, in the absence of W. P. TROWBRIDGE.*
16. C. S LYMAN,* 1867.
17. SIMON NEWCOMB, 1868, in place of A. P. ROCKWELL, called home.
18. O. C. MARSH, 1869.
19. F. W. PUTNAM, 1870, in absence of C. F. HARTT.*
20. F. W. PUTNAM, 1871.
21. EDWARD S. MORSE, 1872.
22. C. A. WHITE, 1873.
23. A. C. HAMLIN, 1874.
24. S. H. SCUDDER, 1875.
25. T. C. MENDENHALL, 1876.
26. AUG. R. GROTE, 1877.
27. H. C. BOLTON, 1878.
28. H. C. BOLTON, 1879, in the absence of GEORGE LITTLE.
29. J. K. REES, 1880.
30. C. V. RILEY, 1881.
31. WILLIAM SAUNDERS, 1882.
32. J. R. EASTMAN, 1883.
33. ALFRED SPRINGER, 1884.
34. C. S. MINOT, 1885.
35. S. G WILLIAMS, 1886.
36. WILLIAM H. PETTEE, 1887.
37. JULIUS POHLMAN, 1888.
38. C. LEO MEES, 1889.
39. H. C. BOLTON, 1890.
40. H. W. WILEY, 1891.
41. A. W. BUTLER, 1892.
42. T. H. NORTON, 1893.
43. H. L. FAIRCHILD, 1894.
44. JAS. LEWIS HOWE, 1895.

Permanent Secretaries, 1851–

5–7. SPENCER F. BAIRD,* 1851–3.
8–17. JOSEPH LOVERING,* 1854–68.
18. F. W. PUTNAM, 1869, in the absence of J. LOVERING.*
19–21. JOSEPH LOVERING,* 1870–72.
22–23. F. W. PUTNAM, 1873–74.
24–28. F. W. PUTNAM, 1875–79.
29–33. F. W. PUTNAM, 1880–84.
34–38. F. W. PUTNAM, 1885–89.
39–43. F. W. PUTNAM, 1890–94.
44–48. F. W. PUTNAM, 1895–99.

Assistant General Secretaries, 1882-1887.

31. J. R. EASTMAN, 1882.
32. ALFRED SPRINGER, 1883.
33. C. S. MINOT, 1884, in the absence of E. S. HOLDEN.
34. S. G. WILLIAMS, 1885, in the absence of C. C. ABBOTT.
35. W. H. PETTEE, 1886.
36. J. C. ARTHUR, 1887.

Secretaries of the Council, 1888–

37. C. LEO MEES, 1888.
38. H. C. BOLTON, 1889.
39. H. W. WILEY, 1890.
40. A. W. BUTLER, 1891.
41. T. H. NORTON, 1892.
42. H. LEROY FAIRCHILD, 1893.
43. JAS. LEWIS HOWE, 1894.
44. CHARLES R. BARNES, 1895.

Secretaries of Section A.—Mathematics, Physics and Chemistry, 1875–81.

24. S. P. LANGLEY, 1875. T. C. MENDENHALL, 1875.
25. A. W. WRIGHT, 1876.
26. H. C. BOLTON, 1877.
27. F. E. NIPHER, 1878.
28. J. K. REES, 1879.
29. H. B. MASON, 1880.
30. E. T. TAPPAN, 1881, in the absence of JOHN TROWBRIDGE.

Secretaries of Section B.— Natural History, 1875-81.

24. EDWARD S. MORSE, 1875.
25. ALBERT H. TUTTLE, 1876.
26. WILLIAM H. DALL, 1877.
27. GEORGE LITTLE, 1878.
28. WILLIAM H. DALL, 1879, in the absence of A. C. WETHERBY.
29. CHARLES V. RILEY, 1880.
30. WILLIAM SAUNDERS, 1881.

SECRETARIES OF SUBSECTIONS, 1875-81.

Subsection of Chemistry.

24. F. W. CLARKE, 1875.
25. H. C. BOLTON, 1876.
26. P. SCHWEITZER, 1877.
27. A. P. S. STUART, 1878.
28. W. R. NICHOLS,* 1879.
29. C. E. MUNROE, 1880.
30. ALFRED SPRINGER, 1881, in the absence of R. B. WARDER.

Subsection of Entomology.

30. B P. MANN, 1881.

Subsection of Anthropology.

24. F. W. PUTNAM, 1875.
25. OTIS T. MASON, 1876.
26, 27. United with Section B.
28, 29, 30. J. G. HENDERSON, 1879–81.

Subsection of Microscopy.

25. E. W. MORLEY, 1876.
26. T. O. SOMMERS, JR., 1877.
27. G. J. ENGELMANN, 1878.
28, 29. A. B. HERVEY, 1879-1880.
30. W. H. SEAMAN, 1881, in the absence of S. P. SHARPLES.

SECRETARIES OF THE SECTIONS, 1882–

Section A.—Mathematics and Astronomy.

31. H. T. EDDY, 1882.
32. G. W. HOUGH, 1883, in the absence of W. W. JOHNSON.
33. G. W. HOUGH, 1884.
34. E. W. HYDE, 1885.
35. S. C. CHANDLER, 1886.
36. H. M. PAUL, 1887.
37. C. C. DOOLITTLE, 1888.
38. G. C. COMSTOCK, 1889.
39. W. W. BEMAN, 1890.
40. F. H. BIGELOW, 1891.
41. WINSLOW UPTON, 1892.
42. C. A. WALDO, 1893, in the absence of A. W. PHILLIPS.
43. J. C. KERSHNER, 1894, in place of W. W. BEMAN, resigned.
44. H. E. MOORE, 1895.

Section B.—Physics.

31. C. S. HASTINGS, 1882.
32. F. E. NIPHER, 1883, in the absence of C. K. WEAD.
33. N. D. C. HODGES, 1884.
34. B. F. THOMAS, 1885, in place of A. A. MICHELSON, resigned.
35. H. S. CARHART, 1886.
36. C. LEO MEES, 1887.
37. ALEX. MACFARLANE, 1888.
38. E. L. NICHOLS, 1889.
39. E. M. AVERY, 1890.
40. ALEX. MACFARLANE, 1891.
41. BROWN AYRES, 1892.
42. W. LECONTE STEVENS, 1893.
43. B. W. SNOW, 1894.
44. E. MERRITT, 1895.

SECRETARIES OF THE SECTIONS, CONTINUED.

Section C.—Chemistry.

31. ALFRED SPRINGER, 1882.
32. { J. W. LANGLEY, 1883. / W. MCMURTRIE, 1883.
33. H. CARMICHAEL, 1884, in the absence of R. B. WARDER.
34. F. P. DUNNINGTON, 1885.
35. W. MCMURTRIE, 1886.
36. C. S. MABERY, 1887.
37. W. L. DUDLEY, 1888.
38. EDWARD HART, 1889.
39. W. A. NOYES, 1890.
40. T. H. NORTON, 1891.
41. JAS. LEWIS HOWE, 1892.
42. H. N. STOKES, 1893, in the absence of J. U. NEF.
43. MORRIS LOEB, 1894, in place of S. M. BABCOCK, resigned.
44. W. P. MASON, 1895.

Section D.—Mechanical Science and Engineering.

31. J. BURKITT WEBB, 1882, in the absence of C. R. DUDLEY.
32. J. BURKITT WEBB, 1883, *pro tempore.*
33. J. BURKITT WEBB, 1884.
34. C. J. H. WOODBURY, 1885.
35. WILLIAM KENT, 1886.
36. G. M. BOND, 1887.
37. ARTHUR BEARDSLEY, 1888.
38. W. B. WARNER, 1889.
39. THOMAS GRAY, 1890.
40. WILLIAM KENT, 1891.
41. O. H. LANDRETH, 1892.
42. D. S. JACOBUS, 1893.
43. JOHN H. KINEALY, 1894.
44. H. S. JACOBY, 1895.

Section E.—Geology and Geography.

31. H. S. WILLIAMS, 1882, in the absence of C. E. DUTTON.
32. A. A. JULIEN, 1883.
33. E. A. SMITH, 1884.
34. G. K. GILBERT, 1885, in the absence of H. C. LEWIS.*
35. E. W. CLAYPOLE, 1886.
36. W. M. DAVIS, 1887, in the absence of T. B. COMSTOCK.
37. JOHN C. BRANNER, 1888.
38. JOHN C. BRANNER, 1889.
39. SAMUEL CALVIN, 1890.
40. W J MCGEE, 1891.
41. R. D. SALISBURY, 1892.
42. W. H. HOBBS, 1893, in place of R. T. HILL, resigned.
43. JED. HOTCHKISS, 1894, in place of W. M. DAVIS, resigned.
44. J. PERRIN SMITH, 1895.

Section F.—Biology, 1882–92.

31. WILLIAM OSLER, 1882, in the absence of C. S. MINOT.
32. S. A. FORBES, 1883.
33. C. E. BESSEY, 1884.
34. J. A. LINTNER, 1885, in place of C. H. FERNALD, resigned.
35. J. C. ARTHUR, 1886.
36. J. H. COMSTOCK, 1887.
37. B. H. FERNOW, 1888.
38. A. W. BUTLER, 1889.
39. J. M. COULTER, 1890.
40. A. J. COOK, 1891.
41. B. D. HALSTED, 1892.

Section F.—Zoölogy.

42. L. O. HOWARD, 1893.
43. JOHN B. SMITH, 1894, in place of WM. LIBBY, jr., resigned.
44. S. A. FORBES, 1895.

SECRETARIES OF THE SECTIONS, CONTINUED.

Section G.—Microscopy, 1882–85.

31. ROBERT BROWN, JR., 1882.
32. CARL SEILER, 1883.
33. ROMYN HITCHCOCK, 1884.
34. W. H. WALMSLEY, 1885.

Section G.—Botany.

42. B. T. GALLOWAY, 1893, in the absence of F. V. COVILLE.
43. CHARLES R. BARNES, 1894.
44. B. T. GALLOWAY, 1895.

Section H.—Anthropology.

31. OTIS T. MASON, 1882.
32. G. H. PERKINS, 1883.
33. G. H. PERKINS, 1884, in the absence of W. H. HOLMES.
34. ERMINNIE A. SMITH,* 1885.
35. A. W. BUTLER, 1886.
36. CHARLES C. ABBOTT, 1887, in absence of F. W. LANGDON.
37. FRANK BAKER, 1888.
38. W. M. BEAUCHAMP, 1889.
39. JOSEPH JASTROW, 1890.
40. W. H. HOLMES, 1891.
41. W. M. BEAUCHAMP, 1892, in place of S. CULIN, resigned.
42. WARREN K. MOOREHEAD, 1893.
43. A. F. CHAMBERLIN, 1894.
44. ANITA NEWCOMB MCGEE, 1895.

Section I.—Economic Science and Statistics.

31. { FRANKLIN B. HOUGH,* 1882. J. RICHARDS DODGE, 1882.
32. JOSEPH CUMMINGS,* 1883.
33. CHARLES W. SMILEY, 1884.
34. CHARLES W. SMILEY, 1885, in absence of J. W. CHICKERING.
35. H. E. ALVORD, 1886.
36. W. R. LAZENBY, 1887.
37. CHARLES S. HILL, 1888.
38. J. RICHARDS DODGE, 1889.
39. B. E. FERNOW, 1890.
40. B. E. FERNOW, 1891.
41. HENRY FARQUHAR, 1892, in place of L. F. WARD made Vice-president.
42. NELLIE S. KEDZIE, 1893.
43. MANLEY MILES, 1894.
44. E. A. ROSS, 1895.

TREASURERS.

1. JEFFRIES WYMAN*, 1848.
2. A. L. ELWYN,* 1849.
3. ST. J. RAVENEL,* 1850, in the absence of A. L. ELWYN.*
4. A. L. ELWYN,* 1850.
5. SPENCER F. BAIRD,* 1851, in absence of A. L. ELWYN.*

6–7. A. L. ELWYN,* 1851–1853.
8. J. L. LECONTE,* 1854, in absence of A. L. ELWYN.*

9–19. A. L. ELWYN,* 1855–1870.
20–30. WILLIAM S. VAUX,* 1871–1881.
32–42. WILLIAM LILLY,* 1882–1893.
43–44. R. S. WOODWARD, 1894–1895.

COMMONWEALTH OF MASSACHUSETTS.

IN THE YEAR ONE THOUSAND EIGHT HUNDRED AND SEVENTY-FOUR.

AN ACT

To Incorporate the "American Association for the Advancement of Science."

Be it enacted by the Senate and House of Representatives, in General Court assembled, and by the authority of the same, as follows:

Section 1. Joseph Henry of Washington, Benjamin Pierce of Cambridge, James D. Dana of New Haven, James Hall of Albany, Alexis Caswell of Providence, Stephen Alexander of Princeton, Isaac Lea of Philadelphia, F. A. P. Barnard of New York, John S. Newberry of Cleveland, B. A. Gould of Cambridge, T. Sterry Hunt of Boston, Asa Gray of Cambridge, J. Lawrence Smith of Louisville, Joseph Lovering of Cambridge and John LeConte of Philadelphia, their associates, the officers and members of the Association, known as the "American Association for the Advancement of Science," and their successors, are hereby made a corporation by the name of the "American Association for the Advancement of Science," for the purpose of receiving, purchasing, holding and conveying real and personal property, which it now is, or hereafter may be, possessed of, with all the powers and privileges, and subject to the restrictions, duties and liabilities set forth in the general laws which now or hereafter may be in force and applicable to such corporations.

Section 2. Said corporation may have and hold by purchase, grant, gift or otherwise, real estate not exceeding one hundred thousand dollars in value, and personal estate of the value of two hundred and fifty thousand dollars.

Section 3. Any two of the corporators above named are hereby authorized to call the first meeting of the said corporation in the month of August next ensuing, by notice thereof "by mail," to each member of the said Association.

Section 4. This act shall take effect upon its passage.

House of Representatives, March 10, 1874.
Passed to be enacted,
John F. Sanford, *Speaker.*

In Senate, March 17, 1874.
Passed to be enacted.
Geo. B. Loring, *President.*

March 19, 1874.
Approved,
W. B. Washburn.

Secretary's Department,
Boston, April 8, 1874.
A true copy, Attest:
David Pulsifer,
Deputy Secretary of the Commonwealth.

CONSTITUTION

OF THE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Incorporated by Act of the General Court of the Commonwealth of Massachusetts.

OBJECTS.

ARTICLE 1. The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of America, to give a stronger and more general impulse and more systematic direction to scientific research, and to procure for the labors of scientific men increased facilities and a wider usefulness.

MEMBERS, FELLOWS, PATRONS AND HONORARY FELLOWS.

ART. 2. The Association shall consist of Members, Fellows, Patrons, Corresponding Members and Honorary Fellows.

ART. 3. Any person may become a Member of the Association upon recommendation in writing by two members or fellows, and election by the Council.

ART. 4. Fellows shall be elected by the Council from such of the members as are professionally engaged in science, or have by their labors aided in advancing science. The election of fellows shall be by ballot and a majority vote of the members of the Council at a designated meeting of the Council.

ART. 5. Any person paying to the Association the sum of one thousand dollars shall be classed as a Patron, and shall be entitled to all the privileges of a member and to all its publications.

ART. 6. Honorary Fellows of the Association, not exceeding three for each section, may be elected; the nominations to be made by the Council and approved by ballot in the respective sections before election by ballot in General Session. Honorary Fellows shall be entitled to all the privileges of Fellows and shall be exempt from all fees and assessments, and entitled to all publications of the Association issued after the date of their election. Corresponding Members shall consist of such scientists not re-

siding in America as may be elected by the Council, and their number shall be limited to fifty. Corresponding Members shall be entitled to all the privileges of members and to the annual volumes of Proceedings published subsequent to their election.

ART. 7. The name of any member or fellow two years in arrears for annual dues shall be erased from the list of the Association, provided that two notices of indebtedness, at an interval of at least three months, shall have been given; and no such person shall be restored until he has paid his arrearages or has been reëlected. The Council shall have power to exclude from the Association any member or fellow, on satisfactory evidence that said member or fellow is an improper person to be connected with the Association, or has in the estimation of the Council made improper use of his membership or fellowship.

ART. 8. No member or fellow shall take part in the organization of, or hold office in, more than one section at any one meeting.

OFFICERS.

ART. 9. The Officers of the Association shall be elected by ballot in General Session from the fellows, and shall consist of a President, a Vice-President from each section, a Permanent Secretary, a General Secretary, a Secretary of the Council, a Treasurer, and a Secretary of each Section; these, with the exception of the Permanent Secretary, shall be elected at each meeting for the following one, and, with the exception of the Treasurer and the Permanent Secretary, shall not be reëligible for the next two meetings. The term of office of Permanent Secretary shall be five years.

ART. 10. The President, or, in his absence, the senior Vice President present, shall preside at all General Sessions of the Association and at all meetings of the Council. It shall also be the duty of the President to give an address at a General Session of the Association at the meeting following that over which he presided.

ART. 11. The Vice Presidents shall be chairmen of their respective Sections, and of their Sectional Committees, and it shall be part of their duty to give an address, each before his own section, at such time as the Council shall determine. The Vice Presidents may appoint temporary chairmen to preside over the sessions of their sections, but shall not delegate their other duties. The Vice Presidents shall have seniority in order of their continuous membership in the Association.

ART. 12. The General Secretary shall be the Secretary of all General Sessions of the Association, and shall keep a record of the business of

these sessions. He shall receive the records from the Secretaries of the Sections, which, after examination, he shall transmit with his own records to the Permanent Secretary within two weeks after the adjournment of the meeting.

ART. 13. The Secretary of the Council shall keep the records of the Council. He shall give to the Secretary of each Section the titles of papers assigned to it by the Council. He shall receive proposals for membership and bring them before the Council.

ART. 14. The Permanent Secretary shall be the executive officer of the Association under the direction of the Council. He shall attend to all business not specially referred to committees nor otherwise constitutionally provided for. He shall keep an account of all business that he has transacted for the Association, and make annually a general report for publication in the annual volume of Proceedings. He shall attend to the printing and distribution of the annual volume of Proceedings, and all other printing ordered by the Association. He shall issue a circular of information to members and fellows at least three months before each meeting, and shall, in connection with the Local Committee, make all necessary arrangements for the meetings of the Association. He shall provide the Secretaries of the Association with such books and stationery as may be required for their records and business, and shall provide members and fellows with such blank forms as may be required for facilitating the business of the Association. He shall collect all assessments and admission fees, and notify members and fellows of their election, and of any arrearages. He shall receive, and bring before the Council, the titles and abstracts of papers proposed to be read before the Association. He shall keep an account of all receipts and expenditures of the Association, and report the same annually at the first meeting of the Council, and shall pay over to the Treasurer such unexpended funds as the Council may direct. He shall receive and hold in trust for the Association all books, pamphlets and manuscripts belonging to the Association, and allow the use of the same under the provisions of the Constitution and the orders of the Council. He shall receive all communications addressed to the Association during the interval between meetings, and properly attend to the same. He shall at each meeting report the names of fellows and members who have died since the preceding meeting. He shall be allowed a salary which shall be determined by the Council, and may employ one or more clerks at such compensation as may be agreed upon by the Council.

ART. 15. The Treasurer shall invest the funds received by him in such securities as may be directed by the Council. He shall annually present to the Council an account of the funds in his charge. No expenditure of the principal in the hands of the Treasurer shall be made without a unanimous vote of the Council, and no expenditure of the income received by the Treasurer shall be made without a two-thirds vote of the Council.

ART. 16. The Secretaries of the Sections shall keep the records of their respective sections, and, at the close of the meeting, give the same, including the records of subsections, to the General Secretary. They shall also be the Secretaries of the Sectional Committees. The Secretaries shall have seniority in order of their continuous membership in the Association.

ART. 17. In case of a vacancy in the office of the President, one of the Vice Presidents shall be elected by the Council as the President of the meeting. Vacancies in the offices of Vice President, Permanent Secretary, General Secretary, Secretary of the Council, and Treasurer, shall be filled by nomination of the Council and election by ballot in General Session. A vacancy in the office of Secretary of a Section shall be filled by nomination and election by ballot in the Section.

ART. 18. The Council shall consist of the past Presidents, and the Vice Presidents of the last meeting, together with the President, the Vice Presidents, the Permanent Secretary, the General Secretary, the Secretary of the Council, the Secretaries of the Sections, and the Treasurer of the current meeting, with the addition of one fellow elected from each Section by ballot on the first day of its meeting. The members present at any regularly called meeting of the Council, provided there are at least five, shall form a quorum for the transaction of business. The Council shall meet on the day preceding each annual meeting of the Association, and arrange the programme for the first day of the sessions. The time and place of this first meeting shall be designated by the Permanent Secretary. Unless otherwise agreed upon, regular meetings of the Council shall be held in the council room at 9 o'clock, A. M., on each day of the meeting of the Association. Special meetings of the Council may be called at any time by the President. The Council shall be the board of supervision of the Association, and no business shall be transacted by the Association that has not first been referred to, or originated with, the Council. The Council shall receive and assign papers to the respective sections; examine and, if necessary, exclude papers; decide which papers, discussions and other proceedings shall be published, and have the general direction of the pub-

lications of the Association; manage the financial affairs of the Association; arrange the business and programmes for General Sessions; suggest subjects for discussion, investigation or reports; elect members and fellows; and receive and act upon all invitations extended to the Association and report the same at a General Session of the Association. The Council shall receive all reports of Special Committees and decide upon them, and only such shall be read in General Session as the Council shall direct. The Council shall appoint at each meeting the following sub-committees who shall act, subject to appeal to the whole Council, until their successors are appointed at the following meeting: 1, on Papers and Reports; 2, on Members; 3, on Fellows.

ART. 19. The Nominating Committee shall consist of the Council, and one member or fellow elected by each of the Sections. It shall be the duty of this Committee to meet at the call of the President and nominate the general officers for the following meeting of the Association. It shall also be the duty of this Committee to recommend the time and place for the next meeting. The Vice President and Secretary of each Section shall be recommended to the Nominating Committee by a sub-committee consisting of the Vice President, Secretary, and three members or fellows elected by the Section.

MEETINGS.

ART. 20. The Association shall hold a public meeting annually, for one week or longer, at such time and place as may be determined by vote of the Association, and the preliminary arrangements for each meeting shall be made by the Local Committee, in conjunction with the Permanent Secretary and such other persons as the Council may designate.

ART. 21. A General Session shall be held at 10 o'clock A. M., on the first day of the meeting, and at such other times as the Council may direct.

SECTIONS AND SUBSECTIONS.

ART. 22. The Association shall be divided into Sections, namely:— A, *Mathematics and Astronomy;* B, *Physics;* C, *Chemistry, including its application to agriculture and the arts;* D, *Mechanical Science and Engineering;* E, *Geology and Geography;* F, *Zoölogy;* G, *Botany;* H, *Anthropology;* I, *Economic Science and Statistics.* The Council shall have power to consolidate any two or more Sections temporarily, and such consolidated Sections shall be presided over by the senior Vice President and Secretary of the Sections comprising it.

ART. 23. Immediately on the organization of a Section there shall be three fellows elected by ballot after open nomination, who, with the Vice President and Secretary and the Vice President and Secretary of the preceding meeting shall form its Sectional Committee. The Sectional Committees shall have power to fill vacancies in their own numbers. Meetings of the Sections shall not be held at the same time with a General Session.

ART. 24. The Sectional Committee of any Section may at its pleasure form one or more temporary Subsections, and may designate the officers thereof. The Secretary of a Subsection shall, at the close of the meeting, transmit his records to the Secretary of the Section.

ART. 25. A paper shall not be read in any Section or Subsection until it has been received from the Council and placed on the programme of the day by the Sectional Committee.

SECTIONAL COMMITTEES.

ART. 26. The Sectional Committees shall arrange and direct the business of their respective Sections. They shall prepare the daily programmes and give them to the Permanent Secretary for printing at the earliest moment practicable. No titles of papers shall be entered on the daily programmes except such as have passed the Council. No change shall be made in the programme for the day in a Section without the consent of the Sectional Committee. The Sectional Committees may refuse to place the title of any paper on the programme; but every such title, with the abstract of the paper or the paper itself, must be returned to the Council with the reasons why it was refused.

ART. 27. The Sectional Committees shall examine all papers and abstracts referred to the sections, and they shall not place on the programme any paper inconsistent with the character of the Association; and to this end they have power to call for any paper, the character of which may not be sufficiently understood from the abstract submitted.

PAPERS AND COMMUNICATIONS.

ART. 28. All members and fellows must forward to the Permanent Secretary, as early as possible, and when practicable before the convening of the Association, full titles of all the papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery, and also such abstracts of their contents as will give a general idea of their nature; and no title shall be referred by the Council to the Sectional Committee until an abstract of the paper or the paper itself has been received.

ART. 29. If the author of any paper be not ready at the time assigned, the title may be dropped to the bottom of the list.

ART. 30. Whenever practicable, the proceedings and discussions at General Sessions, Sections and Subsections shall be reported by professional reporters, but such reports shall not appear in print as the official reports of the Association unless revised by the Secretaries.

PRINTED PROCEEDINGS.

ART. 31. The Permanent Secretary shall have the Proceedings of each meeting printed in an octavo volume as soon after the meeting as possible, beginning one month after adjournment. Authors must prepare their papers or abstracts ready for the press, and these must be in the hands of the Secretaries of the Sections before the final adjournment of the meeting, otherwise only the titles will appear in the printed volume. The Council shall have power to order the printing of any paper by abstract or title only. Whenever practicable, proofs shall be forwarded to authors for revision. If any additions or substantial alterations are made by the author of a paper after its submission to the Secretary, the same shall be distinctly indicated. Illustrations must be provided for by the authors of the papers, or by a special appropriation from the Council. Immediately on publication of the volume, a copy shall be forwarded to every member and fellow of the Association who shall have paid the assessment for the meeting to which it relates, and it shall also be offered for sale by the Permanent Secretary at such price as may be determined by the Council. The Council shall also designate the institutions to which copies shall be distributed.

LOCAL COMMITTEE.

ART. 32. The Local Committee shall consist of persons interested in the objects of the Association and residing at or near the place of the proposed meeting. It is expected that the Local Committee, assisted by the officers of the Association, will make all essential arrangements for the meeting, and issue a circular giving necessary particulars, at least one month before the meeting.

LIBRARY OF THE ASSOCIATION.

ART. 33. All books and pamphlets received by the Association shall be in the charge of the Permanent Secretary, who shall have a list of the same printed and shall furnish a copy to any member or fellow on application. Members and fellows who have paid their assessments in full shall be allowed to call for books and pamphlets, which shall be delivered

to them at their expense, on their giving a receipt agreeing to make good any loss or damage and to return the same free of expense to the Secretary at the time specified in the receipt given. All books and pamphlets in circulation must be returned at each meeting. Not more than five books, including volumes, parts of volumes, and pamphlets, shall be held at one time by any member or fellow. Any book may be withheld from circulation by order of the Council.

Admission Fee and Assessments.

Art. 34. The admission fee for members shall be five dollars in addition to the annual assessment. On the election of any member as a fellow an additional fee of two dollars shall be paid.

Art. 35. The annual assessment for members and fellows shall be three dollars.

Art. 36. Any member or fellow who shall pay the sum of fifty dollars to the Association, at any one time, shall become a Life Member and as such shall be exempt from all further assessments, and shall be entitled to the Proceedings of the Association. All money thus received shall be invested as a permanent fund, the income of which, during the life of the member, shall form a part of the general fund of the Association; but, after his death, shall be used only to assist in original research, unless otherwise directed by unanimous vote of the Council.

Art. 37. All admission fees and assessments must be paid to the Permanent Secretary, who shall give proper receipts for the same.

Accounts.

Art. 38. The accounts of the Permanent Secretary and of the Treasurer shall be audited annually, by Auditors appointed by the Council.

Alterations of the Constitution.

Art. 39. No part of this Constitution shall be amended or annulled, without the concurrence of three-fourths of the members and fellows present in General Session, after notice given at a General Session of a preceding meeting of the Association.

MEMBERS

OF THE

AMERICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE.[1]

PATRONS.[2]

THOMPSON, MRS. ELIZABETH, Stamford, Conn. (22).
LILLY, GEN. WILLIAM, Mauch Chunk, Pa. (28). (Died Dec 1, 1893.)
HERRMAN, MRS. ESTHER, 59 West 56th St., New York, N. Y. (29).

CORRESPONDING MEMBERS.[3]

Monselise, Prof. G., Via Principe Amedeo I, Milano, Italy (40). C
Warington, Robert, F.R.S., Rothamsted, Harpenden, England (40). C

MEMBERS.[4]

Abraham, Abraham, Brooklyn, N. Y. (43).
Adams, C. E., M.D., Ballentine Gymnasium, New Brunswick, N. J. (43). F
Adriance, John S., 231 Broadway, New York, N. Y. (39). C
Aitkin, Miss Clara I., 210 Madison St., Brooklyn, N. Y. (40). H
Aitkin, Miss Helen J , 210 Madison St., Brooklyn, N. Y. (40). E H

[1] The numbers in parentheses indicate the meeting at which the member was elected The black letters at the end of line indicate the sections to which members elect to belong. The Constitution requires that the names of all members two or more years in arrears shall be omitted from the list, but their names will be restored on payment of arrearages. Members not in arrears are entitled to the annual volume of Proceedings bound in paper. *The payment of ten dollars at one time entitles a member to the subsequent volumes to which he may be entitled, bound in cloth, or by the payment of twenty dollars, to such volumes bound in half morocco.*

[2] Persons contributing one thousand dollars or more to the Association are classed as Patrons, and are entitled to the privileges of members and to the publications.

The names of Patrons are to remain permanently on the list.

[3] See ARTICLE VI of the Constitution.

[4] Any Member or Fellow may become a Life Member by the payment of fifty dollars. The income of the money derived from a Life Membership is used for the general purposes of the Association during the life of the member; afterwards it is to be used to aid in original research. Life Members are exempt from the annual assessment, and are entitled to the annual volume. The names of Life Members are printed in small capitals in the regular list of Members and Fellows.

Alden, Jno., Pacific Mills, Lawrence, Mass. (36).
Aldis, Owen F., 230 Monadnock Block, Chicago, Ill. (41). H
Aldrich, Prof. William Sleeper, West Virginia Univ., Morgantown, W. Va. (43).
Allderdice, Wm. H., P. A. Engineer, U. S. Navy, care Navy Department, Washington, D. C. (33). D
Allen, J. M., Hartford, Conn. (22). D
Allen, Prof. Thomas G., Armour Inst., Chicago, Ill. (43). C
Allen, W. F., 24 Park Place, New York, N. Y. (36).
Allen, Walter S., New Bedford, Mass. (39). C I
Alpaugh, Edwin K., Huntington, Ind. (41). E
Andrews, E. R., Rochester, N. Y. (41).
Angell, Geo. W. J., 44 Hudson St., New York, N. Y. (36).
Appleby, Prof. William R.., Univ. of Minnesota, Minneapolis, Minn. (43). D E
Appleton, Rev. Edw. W., D.D., Ashbourne, Montgomery Co., Pa. (28).
Appleton, Prof. William H., Ph.D., Swarthmore College, Swarthmore, Pa. (43). H E
Archambault, U. E., P. O. Box 1944, Montreal, P. Q., Can. (31).
Archbold, Dr. George, 65 Prospect Place, E. 42nd St., New York, N. Y. (40).
Atkinson, Jno. B., Earlington, Hopkins Co., Ky. (26). D
Atwood, E. S., East Orange, N. J. (29). F
Avery, Robert Stanton, 320 A St., S. E., Washington, D. C. (40). A
Avery, Samuel P., 4 E. 38th St., New York, N. Y. (36).
Ayer, Edward Everett, Room 12, The Rookery, Chicago, Ill. (37). H
Ayres, Horace B., Allamuchy, N. J. (40).

Babcock, Wm. H., Washington, D. C. (40).
Backus, Truman J., LL.D., Pres. Packer Inst, Brooklyn, N. Y. (43).
Bacon, Chas. A., Beloit, Wis. (36). A
Baker, Prof. Arthur Latham, 28 Strathallan Park, Rochester, N. Y. (41). A B
Baker, Charles S., Rochester, N. Y. (41). C D
Balch, Samuel W., Yonkers, N. Y. (43).
Balderston, C. Canby, Westtown, Chester Co., Pa. (33). B
Baldwin, Mrs. G. H., 3 Madison Ave., Detroit, Mich. (34). H
Baldwin, Herbert B., 215 Market St., Newark, N. J. (43).
Baldwin, Miss Mary A., 28 Fulton St., Newark, N. J. (31). E H I
Bancroft, Alonzo C., Elma, Erie Co., N. Y. (41).
Banes, Charles H., 1107 Market St., Philadelphia, Pa. (31). D
Bangs, Lemuel Bolton, M.D., 127 E. 34th St., New York, N. Y. (36).
Barclay, Robert. A.M., M.D., 3211 Lucas Ave., St. Louis, Mo. (30).
Barge, B. F., Mauch Chunk, Pa. (33).
Barker, Mrs. Martha M., 26 Eleventh St., Lowell, Mass. (31). E H
Barnard, Charles, 161 W. 79th St., New York, N. Y. (43).
Barnes, David Leonard, A.M., 768–770 Rookery Building, Chicago, Ill. (43). D

Barnhart, Arthur M., 185 Monroe St., Chicago, Ill. (42).
Barnum, Miss Charlotte C., 144 Humphrey St., New Haven, Conn. (36). A
Barrett, Fred. P., Gainesville, Wyoming Co., N. Y. (40). E
Barton, Prof. Samuel M., Virginia A. and M. Coll., Blacksburgh, Va. (43).
Bascom, Miss Florence, Ohio State Univ., Columbus, Ohio (42). E
Baskerville, Charles, Univ. of North Carolina, Chapel Hill, N. C. (41). C
Bastin, Edson Sewell, The Philadelphia Coll. of Pharmacy, Philadelphia, Pa. (39).
Batterson, J. G., Hartford, Conn. (23).
Bausch. Henry, P. O. Drawer 1033, Rochester, N. Y. (41).
Baxter, James N., care H. E. and C. Baxter, cor. Division and Bedford Sts., Brooklyn, N. Y. (36).
Bay, J. Christian, Bacteriologist of the Iowa State Board of Health, Ames, Iowa (42). G
Baylies, Bradford L.B., M.D., 418 Putnam Ave., Brooklyn, N. Y. (43).
Beach, Spencer Ambrose, N. Y. Experiment Station, Geneva, N. Y. (41). G
Bean, Thos. E., Box 441, Galena, Ill. (28). F
Beaver, Daniel B. D., M.D., 150 North 6th St., Reading, Pa. (39).
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[1046 PATRONS, CORRESPONDING MEMBERS AND MEMBERS.]

NOTE.—The omission of an address in the foregoing list indicates that letters directed to that last printed were returned as uncalled for. Information of the present address of the members so indicated is requested by the PERMANENT SECRETARY.

SURVIVING FOUNDERS.

[At the Brooklyn Meeting, 1894, a resolution was unanimously adopted by which all surviving founders of the Association who have maintained an interest in science were made Honorary Life Members of the Association in recognition of their pioneer work in American Science.]

BOUVÉ, THOMAS T., Boston, Mass.
DANA, JAMES D., New Haven, Conn.
DIXWELL, EPES S., Cambridge, Mass.
GREEN, TRAILL, Easton, Pa.
HALL, JAMES, Albany, N. Y.
HUBBARD, BELA, Detroit, Mich.
REDFIELD, J. H., Philadelphia, Pa.
WEST, CHARLES E., Brooklyn, N. Y.

HONORARY FELLOWS.[1]

ROGERS, PROF. WILLIAM B., Boston, Mass. (1). 1881. (Born Dec. 7, 1804. Died May 30, 1882.) **B E**

CHEVREUL, MICHEL EUGÈNE, Paris, France (35). 1886. (Born Aug. 31, 1786. Died April 9, 1889.) **C**

GENTH, DR. F. A., 3937 Locust St., Philadelphia, Pa. (24). 1888. (Born May 17, 1820. Died Feb. 2, 1892.) **C E**

HALL, PROF. JAMES, Albany, N. Y. (1). 1890. **E F**

FELLOWS.[2]

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Arthur, J. C., La Fayette, Ind. (21). 1883. **G**

Ashmead, Wm. H., 1833 M St., N. W., Washington, D. C. (40). 1892. **F**

Atkinson, Edward, 31 Milk St., Boston, Mass. (29). 1881. **I D**

Atkinson, George F., Cornell Univ., Ithaca, N. Y. (39). 1892. **G**

Atwater, Prof. W. O., Wesleyan Univ., Middletown, Conn. (29). 1882. **C**

Atwell, Charles B., 1038 Sherman St., Evanston, Ill. (36). 1890. **F**

Auchincloss, Wm. S., 209 Church St., Philadelphia, Pa. (29). 1886. **D A**

Avery, Elroy M., Ph.D., 657 Woodland Hills Ave., Cleveland, Ohio (37). 1889. **B**

Ayres, Prof. Brown, Tulane Univ., New Orleans, La. (31). 1885. **B**

Babcock, S. Moulton, Madison, Wis. (33). 1885. **C**

Bailey, E. H. S., Lawrence, Douglas Co., Kan. (25). 1889. **C E**

Bailey, Prof. Liberty H., Cornell Univ., Ithaca, N. Y. (34). 1887. **G**

Baker, Frank, M.D., 1315 Corcoran St., Washington, D. C. (31). 1886. **F H**

[1] See ARTICLE VI of the Constitution. [2] See ARTICLE IV of the Constitution.

*** The number in parenthesis indicates the meeting at which the member joined the Association; the date following is the year when made a Fellow; the black letters at end of line are those of the sections to which the Fellow belongs.

When the name is given in small capitals, it designates that the Fellow is also a Life Member.

Baker, Marcus, U. S. Geological Survey, Washington, D. C. (30). 1882. **A**

Baldwin, Judge Charles C., 1264 Euclid Ave., Cleveland, Ohio (37). 1891. **H I**

Ballard, Harlan H., 50 South St., Pittsfield, Mass. (31). 1891. **E F**

Barker, Prof. G. F., 3909 Locust St., Philadelphia, Pa. (13). 1875. **B C**

Barnes, Prof. Chas. R., Madison, Wis. (33). 1885. **G**

Bartlett, Prof. Edwin J., Dartmouth College, Hanover, N. H. (28). 1883. **C**

Bartlett, John R., Commander U. S. N., Lonsdale, R. I. (30). 1882. **E B**

Bartley, Elias H., M.D., 21 Lafayette Ave., Brooklyn, N. Y. (33). 1894. **C**

Barus, Carl, Ph.D., 2808 N St., N. W., Washington, D. C. (33). 1887. **B**

Bates, Henry H, Ph.D., U. S. Patent Office, Washington, D. C. (33). 1887. **B A C D**

Battle, Herbert B., Ph.D., Director N. C. Agric. Exper. Station, Raleigh, N. C. (33). 1889. **C**

Bauer, Louis A., U. S. C. and G. Sur., Washington, D. C. (40). 1892. **A**

Bausch, Edward, P. O. Drawer 1033, Rochester, N. Y. (26). 1883. **A B C F**

Beal, Prof. Wm. James, Agricultural College, Ingham Co., Mich. (17). 1880. **G**

Beardsley, Prof. Arthur, Swarthmore College, Swarthmore, Del. Co., Pa. (33). 1885. **D**

Beauchamp, Rev. Wm. M., Baldwinsville, N. Y. (34). 1886. **H**

Bedell, Frederick, Ph.D., Cornell Univ., Ithaca, N. Y. (41). 1894. **B A**

Bell, Alex. Melville, 1525 35th St., Washington, D. C. (31). 1885. **H**

Bell, Robert, M.D., Ass't Director Geological Survey, Ottawa, Ontario, Can. (38). 1889. **E F**

Beman, Wooster W., 19 So. 5th St., Ann Arbor, Mich. (34). 1886. **A**

Benjamin, Marcus, 589 West End Ave., New York, N. Y. (27). 1887. **C**

Benjamin, Rev. Raphael, M.A., 178 E. 70th St., New York, N. Y. (34). 1887. **E F G H**

Bessey, Prof. Charles E., Univ. of Nebraska, Lincoln, Neb. (21). 1880. **G**

Bethune, Rev. C. J. S., Trinity College School, Pt. Hope, Ont., Can. (18). 1875. **F**

Beyer, Dr. Henry G., U. S. N., U. S. Naval Acad., Annapolis, Md. (31). 1884. **F**

Bickmore, Prof. Albert S., American Museum of Natural History, 8th Ave. and 77th St., Central Park, New York, N. Y. (17). 1880. **H**

Bigelow, Prof. Frank H., U. S. Weather Bureau, Washington, D. C. (36). 1888. **A**

Billings, John S., Surgeon U. S. A., Surg. General's Office, Washington, D. C. (32). 1883. **F H**

Bixby, Wm. H., Cap't of Eng. U. S. A., Newport, R. I. (34). 1892. **D**

Blackham, George E., M.D., Dunkirk, N. Y. (25). 1883. **F**

Blake, Clarence J., M.D., 226 Marlborough St., Boston, Mass. (24). 1877. **B F**

Blake, Prof. Eli W., Brown Univ., Providence, R. I. (15). 1874. **B**
Blake, Francis, Auburndale, Mass. (23). 1874. **B A**
Blue, Archibald, Director of the Bureau of Mines, Toronto, Ontario, Can. (35). 1890. **I**
Boardman, Mrs. William D., 38 Kenilworth St., Roxbury, Mass. (28). 1885. **E H**
Boas, Dr. Franz, Peabody Museum, Cambridge, Mass. (36). 1888. **H**
Boerner, Chas. G., Vevay, Switzerland Co., Ind. (29). 1886. **A B E**
Bolley, Henry L., North Dakota Agric. Coll., Fargo, North Dakota (39). 1892. **G**
Bolton, Dr. H. Carrington, University Club, New York, N. Y. (17). 1875. **C**
Bond, Geo. M., care of The Pratt & Whitney Co., Hartford, Conn. (33). 1885. **D**
Booth, Miss Mary A., Longmeadow, Mass. 1894. **F I G**
Bourke, John G., Capt. 3d Cavalry, U. S. A., War Dept., Washington, D. C. (33). 1885. **H**
Bouvé, Thos. T., Boston Soc. Nat. Hist., Boston, Mass. (1). 1875. **E**
Bowditch, Prof. H. P., Jamaica Plain, Mass. (28). 1880. **F B H**
Bowser, Prof. E. A., Rutgers College, New Brunswick, N. J. (28). 1881.
Brackett, Prof. C. F., College of N. Jersey, Princeton, N. J. (19). 1875. **B**
Brackett, Richard N., Associate Prof. of Chemistry, Clemson Agric. College, Fort Hill, S. C. (37). **C E**
Bradford, Royal B., Commander U. S. N., care Navy Dept, Washington, D. C. (31). 1891. **B D**
Branner, Prof. John C., Leland Stanford jr. Univ., Menlo Park, Cal. (34). 1886. **E F**
Brashear, Jno. A., Allegheny, Pa. (33). 1885. **A B D**
Brewer, Prof. Wm. H., New Haven, Conn. (20). 1875. **E F I**
Brinton, D. G., M.D., Media, Pa. (33). 1885. **H**
Britton, Dr. N. L., Columbia College, New York, N. Y. (29). 1882. **G E**
Broadhead, Prof. Garland Carr, University, Columbia, Mo. (27). 1879. **E**
Brooks, Wm. R., Box 714, Geneva, N. Y. (35). 1886. **A B D G**
Brown, Robert, care of Yale College Observatory, New Haven, Conn. (11). 1874.
Brown, Mrs. Robert, New Haven, Conn. (17). 1874.
Brühl, Gustav, cor. John and Hopkins Sts., Cincinnati, Ohio (28). 1886. **H**
Brush, Charles F., Brush Electric Light Co., Cleveland, Ohio (35). 1886. **B**
Brush, Prof. George J., Yale College, New Haven, Conn. (4). 1874. **C E**
Buckhout, W. A., State College, Centre Co., Pa. (20). 1881. **F**
Burgess, Dr. Thomas J. W., Med. Sup't, Protestant Hospital for the Insane, Montreal, P. Q., Can. (38). 1889. **G**
Burr, Prof. William H., School of Mines, 41 East 49th St., New York, N. Y. (31). 1883.
Butler, A. W., Brookville, Franklin Co., Ind. (30). 1885. **F H**

Caldwell, Prof. Geo. C., Cornell University, Ithaca, N. Y. (23). 1875. **C**

Calvin, Prof. Samuel, State Univ. of Iowa, Iowa City, Iowa (37). 1889. **E F**

Campbell, Prof. Douglas H., Menlo Park, Cal. (34). 1888. **G**

Canby, William M., 1101 Delaware Avenue, Wilmington, Del. (17). 1878. **G**

Carhart, Prof. Henry S., University of Michigan, Ann Arbor, Mich. (29). 1881. **B**

Carleton, M. A., Dep't Agric., Div. of Vegetable Pathology, Washington, D. C. (42) 1894. **G**

Carpenter, Louis G., Agricultural College, Fort Collins, Col. (32). 1889. **A B**

Carpenter, Capt. W. L., U. S. A., care Adjutant General, Washington, D. C. (24). 1877. **F E**

Carpmael, Charles, Director of Magnetic Observatory, Toronto, Ontario, Can. (31). 1883. **B**

Carr, Lucien, Brattle St., Cambridge, Mass. (25). 1877. **H**

Casey, Thomas L., 1419 K St., N. W., Washington, D. C. (38). 1892. **F**

Chamberlain, Alexander F., Clark Univ., Worcester, Mass. (38). 1890. **H**

Chamberlin, T. C., 5041 Madison Ave., Chicago, Ill. (21). 1877. **E B F H**

Chandler, Prof. C. F., School of Mines, Columbia Coll., East 49th St., cor. 4th Ave., New York, N. Y. (19). 1875. **C**

Chandler, Prof. Charles Henry, Ripon, Wis. (28). 1883. **A B**

Chandler, Seth C., jr., 16 Craigie St., Cambridge, Mass. (29). 1882. **A**

Chandler, Prof. W. H., South Bethlehem, Pa. (19). 1894. **C**

Chanute, O., 413 E. Huron St., Chicago, Ill. (17). 1877. **D I**

Cheney, Lellen Sterling, 1081 W. Johnson St., Madison, Wis. (42). 1894. **G**

Chester, Prof. Albert H., Rutgers College, New Brunswick, N. J. (29). 1882. **C F**

Christie, James, Pencoyd, Pa. (33). 1894. **D**

Christy, Prof. Samuel B., Box 41, Berkeley, Cal. (35). 1894. **D**

Chute, Horatio N., Ann Arbor, Mich. (34). 1889. **B C A**

Clapp, Miss Cornelia M., Mt. Holyoke College, South Hadley, Mass. (31). 1883. **F**

Clark, Alvan G., Cambridgeport, Mass. (28). 1880. **A B**

Clark, Prof. John E., 445 Orange St., New Haven, Conn. (17). 1875. **A**

Clark, Wm. Bullock, Ph.D., Johns Hopkins Univ., Baltimore, Md. (37). 1891. **E**

Clarke, Prof. F. W., U. S. Geological Survey, Washington, D. C. (18). 1874. **C**

Claypole, Prof. Edw. W., 603 Buchtel Ave., Akron, Ohio (30). 1882. **E F**

Cloud, John W., 974 Rookery, Chicago, Ill. (28). 1886. **A B D**

Coffin, Prof. Selden J., Lafayette College, Easton, Pa. (22). 1874. **A I**

Cogswell, W. B., Syracuse, N. Y. (33). 1891. **D**

Colburn, Richard T., Elizabeth, N. J. (31). 1894. **I F H**

Cole, Prof. Alfred D., Denison Univ., Granville, Ohio (39). 1891. **B C**

Collin, Prof. Alonzo, Cornell College, Mount Vernon, Iowa (21). 1891. **B C**

Collingwood, Francis, Elizabeth, N. J. (36). 1888. **D**

Colvin, Verplanck, Supt. N. Y. State Adirondack Survey, Albany, N. Y. (28). 1880. **E**

Comstock, Prof. Geo. C., Washburn Observ., Univ. of Wisconsin, Madison, Wis. (34). 1887. **A**

Comstock, J. Henry, 48 East Ave., Ithaca, N. Y. (28). 1882. **F**

Comstock, Prof. Theo. B., President Univ. of Arizona, Tucson, Arizona (24). 1877. **D E B**

Conant, Prof. L. L., Polytechnic Inst., Worcester, Mass. (39). 1892. **A**

Cook, Prof. A. J., Pomona College, Claremont, Cal. (24). 1880. **F**

Cook, Prof. Chas. Sumner, Santa Barbara, Cal. (36). 1889. **B**

Cook, Prof. Orator F., Huntington, N. Y. (40). 1892. **G**

Cooley, Prof. Le Roy C., Vassar College, Poughkeepsie, N. Y. (19). 1880. **B C**

Cooley, Prof. Mortimer E., Univ. of Michigan, Ann Arbor, Mich. (33). 1885. **D**

Cope, Prof. Edward D., 2102 Pine St., Philadelphia, Pa. (17). 1875. **F E**

Corthell, Elmer L., 71 Broadway, New York, N. Y. (34). 1886. **D**

Coulter, Prof. John M., Lake Forest, Ill. (32). 1884. **G**

Coville, Frederick V., Dept. of Agric., Washington, D. C. (35). 1890. **G**

Cox, Hon. Jacob D., Gilman Ave., Mt. Auburn, Cincinnati, Ohio (30). 1881. **F**

Coxe, Eckley B., Drifton, Luzerne Co., Pa. (23). 1879. **D E**

Cragin, Francis W., Colorado College, Colorado Springs, Col. (29). 1890. **F E H**

Craighill, Col. Wm. P., 9 Pleasant St., Baltimore, Md. (37). 1892. **D**

Crampton, Chas. A., M.D., Office of Internal Revenue, Treasury Department, Washington, D. C. (36). 1887. **C**

Crandall, Prof. Charles S., Fort Collins, Col. (40). 1894.

Crawford, Prof. Morris B., Middletown, Conn. (30). 1889. **B**

Crockett, Charles W., Rensselaer Polytechnic Inst., Troy, N. Y. (39). 1894. **A D**

Crosby, Prof. Wm. O., Boston Society of Natural History, Boston, Mass. (29). 1881. **E**

Cross, Prof. Chas. R., Mass. Institute Technology, Boston, Mass. (29). 1880. **B**

Crozier, A. A., Ann Arbor, Mich. (36). 1891. **G**

Culin, Stewart, 127 South Front St., Philadelphia, Pa. (33). 1890. **H**

Cummings, John, Cummingsville, Woburn, Mass. (18). 1890. **F**

Cushing, Frank H., Bureau of Ethnology, Washington, D. C. (40). 1893. **H**

Cushing, Henry Platt, Adelbert College, Cleveland, Ohio (33). 1888. **E**

Dall, William H., Smithsonian Institution, Washington, D. C. (18). 1874. **H F**

Dana, Edward Salisbury, New Haven, Conn. (23). 1875. **B E**

Dana, Prof. James D., New Haven, Conn. (1). 1875. **E**

Dancy, Frank B., A.B., Analytical and Consulting Chemist, Office and Laboratory, 133½ Fayetteville St., Raleigh, N. C. (33). 1890. **C**

Daniel, John, Vanderbilt Univ., Nashville, Tenn. (38). 1894. **B**

Darton, Nelson H., U. S. Geol. Survey, Washington, D. C. (37). 1893.

Davidson, Prof. Geo., U. S. Coast and Geodetic Survey, San Francisco, Cal. (29). 1881. **A B D**

Davis, Wm. Morris, Cambridge, Mass. (33). 1885. **E B**

Dawson, Sir William, Principal McGill College, Montreal, Can. (10). 1875. **E**

Day, David F., Buffalo, N. Y. (35). 1887. **G**

Day, Fisk H., M.D., 309 Sycamore St., Lansing, Mich. (20). 1874. **E H F**

Dean, George W., P. O. Box 92, Fall River, Mass. (15). 1874. **A**

Denton, Prof. James E., Stevens Institute, Hoboken, N. J. (36). 1888. **D B A**

Derby, Orville A., San Paulo, Brazil, S. A. (39). 1890.

Dimmock, George, P. O. Box 15, Canoble Lake, N. H. (22). 1874. **F**

Dolbear, A. Emerson, Tufts College, Mass. (20). 1880. **B**

Doolittle, Prof. C. L., South Bethlehem, Pa. (25). 1885. **A**

Dorsey, George A., Ph.D. Peabody Museum, Cambridge, Mass. (39). 1892. **H**

Dorsey, Rev. J. Owen, Box 305, Takoma Park, D. C. (31). 1883. **H**

Douglass, Andrew E., Amer. Mus. of Nat. Hist., Central Park, New York, N. Y. (31). 1885. **H**

Draper, Dan'l, Ph.D., Director N. Y. Meteorological Observatory, Central Park, 64th St., Fifth Avenue, New York, N. Y. (29). 1881. **B D F A**

Drown, Prof. Thos. M., Mass. Institute Technology, Boston, Mass. (29). 1881. **C**

Du Bois, Prof. Aug. J., New Haven, Conn. (30). 1882. **A B D**

Du Bois, Patterson, Ass't Editor S.S.T., 1031 Walnut St., Philadelphia, Pa. (33). 1887. **H C I**

Dudley, Charles B., Altoona, Pa. (23). 1882. **C B D**

Dudley, Wm. L., Prof. of Chemistry, Vanderbilt Univ., Nashville, Tenn. (28). 1881. **C**

Dudley, Prof. Wm. R., Leland Stanford jr. Univ., Palo Alto, Cal. (29). 1883. **G**

Dumble, E. T., Austin, Texas (37). 1891. **E**

Dunham, Edw. K., 338 East 26th St., New York, N. Y. (30). 1890.

Dunnington, Prof. F. P., University Station, Charlottesville, Va. (26). 1880. **C**

Dwight, Prof. William B., Vassar College, Poughkeepsie, N. Y. (30). 1882. **E F**

Eastman, Prof. J. R., U. S. Naval Observatory, Washington, D. C. (26). 1879. **A**

Eaton, Prof. D. G., 55 Pineapple St., Brooklyn, N. Y. (19). 1874. **B E**
Eaton, Prof. James R., Liberty, Mo. (29). 1885. **C B E**
Eccles, Robert G., M.D., 191 Dean St., Brooklyn, N. Y. (31). 1894. **F C**
Eddy, Prof. H. T., Rose Polytechnic Inst., Terre Haute, Ind. (24). 1875. **A B D**
Edison, Thos. A., Orange, N. J. (27). 1878. **B**
Egleston, Prof. Thomas, 85 W. Washington Square, New York, N. Y. (27). 1879. **C D E**
Elkin, William L., Yale Coll. Observ., New Haven, Conn. (33). 1885. **A**
Ely, Theo. N., Sup't Motive Power, Penn. R. R., Altoona, Pa. (29). 1886.
Emerson, Prof. Benjamin K., Amherst, Mass. (19). 1877. **E F**
Emerson, Prof. C. F., Box 499, Hanover, N. H. (22). 1874. **B A**
Emery, Albert H., Stamford, Conn. (29). 1884. **D B**
Emery, Charles E., Bennett Building, New York, N. Y. (34). 1886. **D B A**
Emmons, S. F., U. S. Geol. Survey, Washington, D. C. (26). 1879. **E**
Engelmann, George J., M.D., 3003 Locust St., St. Louis, Mo. (25). 1875. **F H**
Ernst, Carl W., 298 Commonwealth Ave., Boston, Mass. (23). 1874. **I H**
Eyerman, John, "Oakhurst," Easton, Pa. (33). 1889. **E C**

Fairbanks, Henry, Ph.D., St. Johnsbury, Vt. (14). 1874. **B D A**
Fairchild, David G., Dept. of Agric., Washington, D. C. (40). 1892. **G**
Fairchild, Prof. H. L., University of Rochester, Rochester, N. Y. (28). 1883. **E F**
Fanning, John T., Consulting Eng., Kasota Block, Minneapolis, Minn. (29). 1885. **D**
Fargis, Rev. Geo. A., Georgetown College, Georgetown, D. C. (40). 1892.
Farlow, Dr. W. G., 24 Quincy St., Cambridge, Mass. (20). 1875. **G**
Farquhar, Henry, Coast Survey Office, Washington, D. C. (33). 1886. **A I F B**
Fernow, Bernhard E., Chief of Forestry Division, Dep't of Agriculture, Washington, D. C. (31). 1887. **G I**
Firmstone, F., Easton, Pa. (33). 1887. **D**
Fiske, Thos. S., A.M., Ph.D., Columbia College, New York, N. Y. (38). 1891. **A**
Fitch, Edward H., Jefferson, Ashtabula Co., Ohio (11). 1874. **I E**
Fletcher, Miss Alice C., care Peabody Museum, Cambridge, Mass. (29). 1883. **H**
Fletcher, James, Dominion Entomologist, Experimental Farm, Ottawa, Ontario, Can. (31). 1883. **F**
Fletcher, Dr. Robert, Army Medical Museum, Washington, D. C. (29). 1881. **F H**
Flint, Albert S., Washburn Observ., Madison, Wis. (30). 1887. **A**
Flint, James M., Surgeon U. S. N., Smithsonian Institution, Washington, D. C. (28). 1882. **F**
Foote, Dr. A. E., 1224–28 N. 41st St., Philadelphia, Pa. (21). 1874. **E C**
Forbes, Prof. S. A., Univ. of Illinois, Champaign, Ill. (27). 1879. **F**

Fox, Oscar C., U. S. Patent Office, Washington, D. C. (36). 1891. **B D A**
Foye, Prof. J. C., Armour Institute, cor. 33d St. and Armour Ave., Chicago, Ill. (29). 1884. **C B**
Franklin, William S., Ames, Iowa (36). 1892.
Frazer, Dr. Persifor, Drexel Building, Room 1042, Philadelphia, Pa. (24). 1879. **E C**
Frazier, Prof. B. W., The Lehigh University, So. Bethlehem, Pa. (24). 1882. **E C**
Frear, Wm., State College, Centre Co., Pa. (33). 1886. **C**
Freer, Prof. Paul C., Ann Arbor, Mich. (39). 1891. **C**
French, Prof. Thomas, jr., Ridgeway Ave., Avondale, Cincinnati, Ohio (30). 1883. **B**
Frisby, Prof. Edgar, U. S. N. Observ., Washington, D. C. (28). 1880. **A**
Frost, Edwin Brant, Hanover, N. H. (33). 1890. **A B**
Fuller, Andrew S., Ridgewood, Bergen Co., N. J. (24). 1882. **F**
Fuller, Prof. Homer T., Pres. Drury Coll., Springfield, Mo. (35). 1891. **C E**
Fulton, Robert B., Chancellor Univ. of Miss., Prof. of Physics and Astronomy, University, Miss. (21). 1887. **B A**

Gaffield, Thomas, 54 Allen St., Boston, Mass. (29). 1889. **C B**
Gage, Prof. Simon Henry, Ithaca, N. Y. (28). 1881. **F**
Galbraith, Prof. John, Toronto, Ontario, Can. (33). 1889.
Galloway, B. T., Dep't of Agriculture, Washington, D. C. (37). 1890. **G**
Gardiner, Dr. Edward G., Massachusetts Institute Technology, Boston, Mass. (29). 1890. **F**
Gibbs, Prof. J. Willard, New Haven, Conn. (33). 1885. **B**
Gilbert, G. K., U. S. Geol. Survey, Washington, D. C. (18). 1874. **E**
Gill, Adam Capen, Cornell Univ., Ithaca, N. Y. (33). 1894. **E**
Gill, Prof. Theo., Columbian Univ., Washington, D. C. (17). 1874. **F**
Gillette, Clarence P., Fort Collins, Col. (37). 1893.
Gillman, Henry, 183 Fort St., West, Detroit, Mich. (24). 1875. **H F**
Gilman, Daniel C., President Johns Hopkins University, Baltimore, Md. (10). 1875. **E H**
Glenn, William, 1348 Block St., Baltimore, Md. (33). 1893. **C**
Goessman, Prof. C. A., Mass. Agricultural College, Amherst, Mass. (18). 1875. **C**
Goff, E. S., 1113 University Ave., Madison, Wis. (35). 1889.
Gold, Theodore S., West Cornwall, Conn. (4). 1887. **B C**
Goldschmidt, S. A., Ph.D., 43 Sedgwick St., Brooklyn, N. Y. (24). 1880. **C E B**
Goldsmith, Edw., 658 No. 10th St., Philadelphia, Pa. (29). 1892. **C B**
Gooch, Frank A., Yale College, New Haven, Conn. (25). 1880. **C**
Goodale, Prof. G. L., Botanic Gardens, Cambridge, Mass. (18). 1875. **G**
Goode, G. Brown, Smithsonian Institution, Washington, D. C. (22). 1874.
Goodfellow, Edward, Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (24). 1879. **A H**

Gould, Dr. B. A., Cambridge, Mass. (2). 1875. **A B**
GRANT, MRS. MARY J., Brookfield, Conn. (23). 1874. **A**
Grant, Ulysses S., Ph.D., Geol. Survey of Minnesota, Minneapolis, Minn. (39). 1893. **E**
Gratacap, L. P., Ph.B., 77th St. and 8th Ave., New York, N. Y. (27). 1884. **C E F**
Gray, Prof. Thomas, Terre Haute, Ind. (38). 1889.
Green, Arthur L., La Fayette, Ind. (33). 1888. **C**
GREEN, TRAILL, M.D., Easton, Pa. (1). 1874. **C F**
Griffith, Ezra H., 5656 Washington Ave., Chicago, Ill. (39). 1892. **B F**
Grimes, J. Stanley, Room 18, 115 Monroe St., care Newark Life Ins. Co., Chicago, Ill. (17). 1874. **E H**
Grinnell, George Bird, 40 Park Row, New York, N. Y. (25). 1885. **F E**
Griswold, Leon Stacy, 238 Boston St., Dorchester, Mass. (38). 1893. **E**

Hague, Arnold, U. S. Geol. Survey, Washington, D. C. (26). 1879.
Haines, Reuben, Haines and Chew St., Germantown, Philadelphia, Pa. (27). 1889. **C B**
Hale, Albert C., Ph.D., No. 551 Putnam Ave., Brooklyn, N. Y. (29). 1886. **C B**
Hale, Geo. E., Director of the Observatory, Univ. of Chicago, Chicago, Ill. (37). 1891. **A B C**
Hale, Horatio, Clinton, Ontario, Can. (30). 1882. **H**
Hale, William H., Ph.D., 40 First Place, Brooklyn, N. Y. (19). 1874. **I F H C B E A**
Hall, Prof. Asaph, 2715 N. St., Georgetown, D. C. (25). 1877. **A**
Hall, Asaph, jr., Univ. of Mich, Ann Arbor, Mich. (38). 1890. **A**
Hall, Prof. C. W., 803 Univ. Ave. So., Minneapolis, Minn. (28). 1883. **E**
Hall, Prof. Edwin H., 5 Avon St., Cambridge, Mass. (29). 1881. **B**
Hall, Prof. Lyman B., Haverford College, Haverford, Pa. (31). 1884. **C**
Hallock, Dr. William, Columbia College, New York, N. Y. (40). 1893. **B E**
Hallowell, Miss Susan M., Wellesley Coll., Wellesley, Mass. (33). 1890. **G**
Halsted, Byron D., New Jersey Agricultural Experiment Station, New Brunswick, N. J. (29). 1883. **G**
Hambach, Dr. G., 1319 Lami St., St. Louis, Mo. (26). 1891. **F E**
HANAMAN, C. E., Troy, N. Y. (19). 1883. **F**
Hargitt, Prof. Charles W., Syracuse, N. Y. (38). 1891. **F**
HARKNESS, PROF. WILLIAM, U. S. N. Observatory, Washington, D. C. (26). 1878. **A B C D**
Harris, Gilbert D., Ithaca, N. Y. (37). 1893.
Harris, Uriah R., Lieutenant U. S. N., Columbus, Ind. (34). 1886. **A**
Hart, Edw., Ph.D., Easton, Pa. (33). 1885. **C**
Hasbrouck, Prof. I. E., 364 Carlton Ave., Brooklyn, N. Y. (23). 1874. **D A I**
HASTINGS, C. S., Sheffield Scientific School of Yale College, New Haven, Conn. (25). 1878. **B**
Haupt, Prof. Lewis M., University of Pennsylvania, Philadelphia, Pa. (32). 1885. **I D E**

Haynes, Prof. Henry W., 239 Beacon St., Boston, Mass. (28). 1884. **H**
Heal, Wm. E., Marion, Ind. (39). 1891. **A**
Heitzmann, Dr. Charles, 39 W. 45th St., New York, N. Y. (36). 1890.
Hering, Rudolph, Civil and Sanitary Engineer, 277 Pearl St., New York, N. Y. (33). 1885. **D E I**
Hervey, Rev. A. B., President St. Lawrence University, Canton, N.Y. (22). 1879. **F**
Hilgard, Prof. E. W., University of California, Berkeley, Cal. (11). 1874. **C E B**
Hill, Robert Thomas, U. S. Geol. Survey, Washington, D. C. (36). 1889. **E**
Himes, Prof. Charles F., Carlisle, Pa. (29). 1882. **B C**
Hinrichs, Dr. Gustavus, 3132 Lafayette Ave., St. Louis, Mo. (17). 1874. **C B**
Hirschfelder, Chas. A., Vice Consul U. S. A., Toronto, Ontario, Can. (33). 1887. **H**
Hitchcock, Albert Spear, Manhattan, Kan. (39). 1892. **G**
Hitchcock, Prof. Charles H., Hanover, N. H. (11). 1874. **E**
Hobbs, William Herbert, Ph.D., Madison, Wis. (41). 1893. **E**
Hodges, N. D. C., 874 Broadway, New York, N. Y. (29) 1882. **B**
Hoffmann, Dr. Fred., "Rundschau," P. O. Box 1680, New York, N. Y. (28). 1881. **C F**
Holden, Prof. E. S., Mt. Hamilton, Cal. (23). 1875. **A**
Hollick, Arthur, Columbia College, New York, N. Y. (31). 1892. **G E**
Holm, Theodor, U. S. Natl. Museum, Washington, D. C. (40). 1892. **F**
Holmes, Prof. Jos. A., Chapel Hill, N. C. (33). 1887. **E F**
Holmes, Wm. H., Field Columbian Mus., Chicago, Ill. (30). 1883. **H**
Holway, E. W. D., Decorah, Iowa (33). 1890. **G**
Horton, S. Dana (37). 1889. **I**
Hosea, Lewis M., Johnston Building, Cincinnati, Ohio (30). 1883. **B H**
Hotchkiss, Major Jed., Staunton, Va. (31). 1883. **E H I**
Hough, Prof. G. W., Northwestern Univ., Evanston, Ill. (15). 1874. **A**
Hough, Walter, U. S. National Museum, Washington, D. C. (38). 1890.
Hovey, Rev. Horace C., 60 High St., Newburyport, Mass. (29). 1883. **E H**
Howard, Prof. Curtis C., 97 Jefferson Ave., Columbus, Ohio (38). 1892. **C**
Howard, Leland O., Dep't of Agric., Washington, D. C. (37). 1889. **F**
Howe, Charles S., Prof. of Mathematics, Case School of Applied Science, Cleveland, Ohio (34). 1891. **A**
Howe, Prof. Jas. Lewis, Washington and Lee Univ., Lexington, Va. (36). 1888. **C**
Howell, Edwin E., 612 17th St., N. W., Washington, D. C (25). 1891. **E**
Hubbard, Gardiner Greene, 1328 Conn. Ave., Washington, D. C. (40) 1893. **E**
Hulst, Rev. Geo. D., 15 Himrod St., Brooklyn, N. Y. (29). 1887. **F**
Humphreys, W. J., Johns Hopkins Univ., Baltimore, Md. (42). 1894. **B**
Hunt, Alfred E., 116 Water St., Pittsburgh, Pa. (35). 1891. **C D**

Hunt, George, 119 Prospect St., Providence, R. I. (9). 1874.
Hyatt, Prof. Alpheus, Natural History Society, Boston, Mass. (18). 1875. **E**
Hyde, Prof. E. W., Station D, Cincinnati, Ohio (25). 1881. **A**

Iddings, Joseph P., U. S. Geological Survey, Washington, D. C. (31). 1884. **E**
Irby, Prof. B., Raleigh, N. C. (37). 1891. **F**

Jack, John G., Jamaica Plain, Mass. (31). 1890. **G**
Jackson, Robert T., 33 Gloucester St., Boston, Mass. (37). 1890. **F**
Jacobus, David S., Stevens Institute, Hoboken, N. J. (36). 1889. **D B A**
Jacoby, Harold, Columbia College, New York, N. Y. (38). 1891. **A**
Jacoby, Henry S., in charge of Bridge Engineering and Graphics, College of Civil Eng., Cornell Univ., Ithaca, N. Y. (36). 1892. **D**
James, Jos. F., M.S., U. S. Dept. of Agric., Washington, D. C. (30). 1882. **F E**
Jastrow, Dr. Jos., Univ. of Wisconsin, Madison, Wis. (35). 1887. **H F**
Jayne, Horace F., 1826 Chestnut St., Philadelphia, Pa. (29). 1884. **F H**
Jeffries, B. Joy, M.D., 15 Chestnut St., Boston, Mass. (29). 1881. **F H**
Jenkins, Edw. H., New Haven, Conn. (33). 1885. **C**
Jenkins, Prof. Oliver P., Leland Stanford jr. Univ., Menlo Park, Cal. (39). 1891. **F**
Jenks, Elisha T., Middleborough, Mass. (22). 1874. **D**
Jesup, Prof. Henry G., Dartmouth College, Hanover, N. H. (36). 1891. **F**
Jesup, Morris K., 44 Pine St., New York, N. Y. (29). 1891. **I**
Jewell, Theo. F., Commander U. S. Navy, Navy Yard, Washington, D. C. (25). 1882. **B**
Jillson, Dr. B. C., 6224 Station St., E.E., Pittsburgh, Pa. (14). 1881. **E H F**
Johnson, John B., Washington Univ., St. Louis, Mo. (33). 1886. **D**
Johnson, Otis C., 52 Thayer St., Ann Arbor, Mich. (34). 1886. **C**
Jones, Lewis R., Burlington, Vt. (41). 1894. **G**
Jones, Prof. Marcus E., Salt Lake City, Utah (40). 1893.
Jordan, Prof. David S., Palo Alto, Menlo Park P. O., Cal. (31). 1883. **F**
Julien, A. A., New York Acad. of Sciences, New York, N. Y. (24). 1875. **E C**

Kedzie, Mrs. Nellie S., Manhattan, Kan. (34). 1890. **I F**
Kedzie, Prof. Robert C., Agricultural College, Mich. (29). 1881. **C**
Kellerman, Prof. William A., Ohio Univ., Columbus, Ohio (41). 1893. **G**
Kellicott, David S., Columbus, Ohio (31). 1883. **F**
Kemp, James F., School of Mines, Columbia College, New York, N. Y. (36). 1888. **E**
Kendall, Prof. E. Otis, 3826 Locust St., Philadelphia, Pa. (29). 1882. **A**
Kent, William, Passaic, N. J. (26). 1881. **D I**

Kershner, Prof. Jefferson E., Lancaster City, Pa. (29). 1883. **A B**
Kenealy, John H., Washington Univ., St. Louis, Mo (36). 1891. **D**
King, F. H., Experiment Station, Madison, Wis. (32). 1892. **E F**
Kirkwood, Prof. Daniel, Arlington Ave., Riverside, Cal. (7). 1874. **A**
Klotz Otto Julius. 437 Albert St., Ottawa, Ontario, Can. (38). 1889.
Knorr, Aug. E., 1109 14th St., N. W., Washington, D. C. (40). 1893. **C**
Knowlton, Frank H., U. S. National Museum, Washington, D. C. (33). 1893. **G E**
Kunz, G. F., care Messrs. Tiffany & Co., Union Square, New York, N. Y. (29). 1883. **E H C**

Lacoe, Ralph D., Pittston, Pa (31). 1893. **E F**
Laflamme, Prof. J. C. K., Laval Univ., Quebec, Can. (29). 1887. **E B**
LaFlesche, Francis, Indian Bureau, Interior Dep't, Washington, D. C. (33). 1885. **H**
Lamb, Daniel S., M.D., 800 10th St., N. W., Washington, D. C. (40). 1894. **H**
Lamborn, Robert H., 32 Nassau St., New York, N. Y. (28). 1887. **H E F**
Landreth, Olin H., Prof. of Civil Engineering, Union College, Schenectady, N. Y. (28). 1883. **D**
Langdon, Dr. F. W., 65 West 7th St., Cincinnati, Ohio (30). 1882. **F H**
Langley, Prof. S. P., Secretary Smithsonian Institution, Washington, D. C. (18). 1874. **A B**
Lanza, Prof. Gaetano, Mass. Institute of Technology, Boston, Mass. (29). 1882. **D A B**
Larkin, Edgar L., Director Knox College Observatory, Galesburg, Ill. (28). 1883. **A**
Lattimore, Prof. S. A., University of Rochester, Rochester, N. Y. (15). 1874. **C**
Laudy, Louis H., Ph.D., School of Mines, Columbia College, New York, N. Y. (28). 1890. **C**
Lawrence, George N., 45 E. 21st St., New York, N. Y. (7). 1877. **F**
Lazenby, Prof. Wm. R., Columbus, Ohio (30). 1882. **B I**
LeBrun, Mrs. Michel, 245 West 23d St., New York, N. Y. (35). 1892. **F**
LeConte, Prof. Joseph, Univ. of Cal., Berkeley, Cal. (29). 1881. **E F**
Ledoux, Albert R., Ph.D., 9 Cliff St., New York, N. Y. (26). 1881. **C**
Leeds, Prof. Albert R., Stevens Institute, Hoboken, N. J. (23). 1874. **C F**
Lefavour, Prof. Henry, Williams Coll., Williamstown, Mass. (42). 1894.
Lehmann, G. W., Ph.D., 412 East Lombard St., Baltimore, Md. (30). 1885. **C B**
Lennon, William H., Brockport, N. Y. (31). 1894. **G C**
Lesley, Prof. J. Peter, State Geologist of Pennsylvania, 1008 Clinton St., Philadelphia, Pa. (2). 1874. **E**
Leverett, Frank, Denmark, Iowa (37). 1891. **E**
Libbey, Prof. William, jr., Princeton, N. J. (29). 1887. **E F**

Lindahl, Josua, Ph.D., State Geologist, Springfield, Ill. (40). 1892. **F E**
Lindenthal, Gustav, C.E., 45 Cedar St., New York, N. Y. (37). 1891. **I**
Lintner, J. A., N. Y. State Entomologist, Room 27, Capitol, Albany, N. Y. (22). 1874. **F**
Lloyd, John Uri, Pharmaceutical Chemist, Court and Plum Sts., Cincinnati, Ohio (38). 1890. **C F**
Lloyd, Mrs. Rachel, Box 675, Lincoln, Neb. (31). 1889. **C**
Locy, Prof. Wm. A., Lake Forest, Ill. (34). 1890. **F**
Loeb, Morris, Ph.D., 37 E. 38th St., New York, N. Y. (36). 1889. **C**
Loud, Prof. Frank H., 1203 N. Tejon St., Colorado Springs, Col. (29). **A B**
Loughridge, Dr. R. H., Ass't Prof. Agric. Chem. and Agric. Geol., Univ. of California, Berkeley, Cal. (21). 1874. **E C**
Love, Edward G., 69 E. 54th St., New York, N. Y. (24). 1882. **C**
Low, Seth, Pres. Columbia Coll., New York, N. Y. (29). 1890.
Lyle, David Alexander, Captain Ordnance Dept. U. S. A., Ordnance Office, War Dept., Washington, D. C. (28). 1880. **D**
Lupton, Prof. N. T., Auburn, Lee Co., Ala. (17). 1874. **C**
Lyon, Dr. Henry, 34 Monument Sq., Charlestown, Mass. (18). 1874.

McAdie, Alexander George, U. S. Weather Bureau, Washington, D. C. (40). 1892. **B**
McBride, Prof. Thomas H., Iowa City, Iowa (38). 1890. **G**
McCauley, Capt. C. A. H., Ass't Q. M., U. S. A., Portland, Oregon (29). 1881.
McCreath, Andrew S., 223 Market St., Harrisburg, Pa. (33). 1889. **C E**
McDonnell, Prof. Henry B., College Park, Md. (40). 1893. **C**
McGee, Dr. Anita Newcomb, Bureau of American Ethnology, Washington, D. C. (37). 1892. **H**
McGee, W J, Bureau of American Ethnology, Washington, D. C. (27). 1882. **H E**
McGill, John T., Ph.D., Vanderbilt Univ., Nashville, Tenn. (36). 1888. **C**
McGregory, Prof. J. F., Colgate Univ., Hamilton, N. Y. (35). 1892.
McGuire, Joseph D., Ellicott City, Md. (30). 1891. **H**
McMahon, James, Ithaca, N. Y. (36). 1891. **A**
MacMillan, Prof. Conway, Univ. of Minnesota, Minneapolis, Minn. (42). 1894. **G**
McMurtrie, William, 106 Wall St., New York, N. Y. (22). 1874. **C**
McNeill, Malcolm, Lake Forest, Ill. (32). 1885. **A**
McRae, Austin Lee, Rolla, Mo. (39). 1891. **B**
Mabery, Prof. C. F., Case School of Applied Science, Cleveland, Ohio (29). 1881. **C**
Macfarlane, Prof. A., Austin, Texas (34). 1886. **B A**
Macloskie, Prof. George, College of New Jersey, Princeton, N. J. (25). 1882. **F**
Magie, Prof. William F., College of New Jersey, Princeton, N. J. (35). 1887.

MANN, B. PICKMAN, 1918 Sunderland Place, Washington, D. C. (22). 1874 I F

Marcy, Oliver, LL.D., Evanston, Ill. (10). 1874. E

Mark, Prof. E. H., Louisville, Ky. (39). 1893. B

Marsh, Prof. C. Dwight, Ripon, Wis. (34). 1893. F E

MARSH, PROF. O. C., Yale College, New Haven, Conn. (15). 1874. F H

Martin, Artemas, U. S. Coast Survey, Washington, D. C. (38). 1890. A

Martin, Prof. Daniel S., 236 West 4th St., New York, N. Y. (23). 1879. E F

Martin, Miss Lillie J., Girl's High School, San Francisco, Cal. (32). 1886. F C

Martin, Prof. Wm. J., Davidson College, N. C. (31). 1884. C E

Marvin, C. F., Signal Office, Washington, D. C. (39). 1892. B

Marvin, Frank O., Univ. of Kansas, Lawrence, Kan. (35). 1894. D

Mason, Prof. Otis T., Nat'l Museum, Washington, D. C. (25). 1877. H

Mason, Dr. William P., Prof. Rensselaer Polytechnic Inst., Troy, N. Y. (31). 1886. C

Matthews, Dr. Washington, 1262 New Hampshire Ave., cor. 21st St., N. W., Washington, D. C. (37). 1888. H

Maxwell, Walter, Dept. of Agriculture, Washington, D. C. (40). 1892. C

Mayer, Prof. A. M., Stevens Inst. of Technology, Hoboken, N. J. (19). 1874.

Meehan, Thomas, Germantown, Pa. (17). 1875 G

Mees, Prof. Carl Leo, Rose Polytechnic Inst., Terre Haute, Ind. (24). 1876. B C

Mendenhall, Prof. T. C., President Worcester Polytechnic Institute, Worcester, Mass. (20). 1874. B

Mercer, H. C. Doylestown, Bucks Co., Pa. (41). 1893.

Merrill, Frederick J. H., Ph.D., Ass't Director New York State Museum, Albany, N. Y. (35). 1887. E

Merriman, C. C., 1910 Surf St., Lake View, Chicago, Ill. (29). 1880. F

Merriman, Prof. Mansfield, So. Bethlehem, Pa. (32). 1885. A D

Merritt, Ernest, Ithaca, N. Y. (33). 1890.

Metcalf, William, Pittsburgh, Pa. (33). 1894. D

Michael, Mrs. Helen Abbott, Torwood, Bonchurch, Isle of Wight, England (33). 1885. C F

Miles, Prof. Manly, Lansing, Mich. (29). 1890. F I

Mills, Wesley, Montreal, P. Q., Can. (31). 1886. F H

Millspaugh, C. F., M.D., Field Columbian Museum, Chicago, Ill. (40). 1892. G

Minot, Dr. Charles Sedgwick, Harvard Medical School, Back Bay, Boston, Mass. (28). 1880. F

Minot, Francis, M.D., 65 Marlborough St., Boston, Mass. (29). 1884.

Mixter, Prof. Wm. G., New Haven, Conn. (30). 1882. C

Moler, Geo. S., 106 University Ave., Ithaca, N. Y. (38). 1892.

Moody, Robert O., M.D., Fair Haven Heights, New Haven, Conn. (35). 1892. F

Mooney, James, Bureau of Ethnology, Washington, D. C. (38). 1890. **H**
Moore, E. Hastings, The Univ. of Chicago, Chicago, Ill. (39). 1891. **A**
Moore, Prof. J. W., M.D., Lafayette College, Easton, Pa. (22). 1874. **B D A**
Moore, Veranus A., M.D., Bureau of Animal Industry, Dept. of Agric., Washington, D. C. (40). 1892. **F**
Moorehead, Warren K., Xenia, Ohio (38). 1890. **H**
Moreland, Prof. S. T., Lexington, Va. (33). 1894. **B D**
Morley, Prof. Edward W., 23 Cutler St., Cleveland, Ohio (18). 1876. **C B E**
Morse, Prof. E. S., Salem, Mass. (18). 1874. **F H**
Morton, H., Stevens Institute Technology, Hoboken, N. J. (18). 1875. **B C**
Moser, Lieut. Comd'r Jeff. F., U. S. N., Hydrographic Inspector, C. and G. Survey, Washington, D. C. (28). 1889. **E**
Moses, Prof. Thomas F., Urbana University, Urbana, Ohio (25). 1883. **H F**
Munroe, Prof. C. E., Columbian Univ., Washington, D. C. (22). 1874. **C**
Murdoch, John, Rock, Plymouth Co., Mass. (29). 1886. **F H**
Murtfeldt, Miss Mary E., Kirkwood, Mo. (27). 1881. **F**
Myers, John A., Agric. Exper. Station, Morgantown, W. Va. (30). 1889. **C**

Nagle, Prof. James C., A. and M. Coll., College Station, Texas (40). 1893. **D B**
Nason, Frank L., 5 Union St., New Brunswick, N. J. (36). 1888. **E**
Nason, Prof. H. B., Rensselaer Polytechnic Institute, Troy, N. Y. (13). 1874. **C E**
Nef, J. U., Univ. of Chicago, Chicago, Ill. (39). 1891. **C**
Nelson, Prof. A. B., Centre College, Danville, Ky. (30). 1882. **A B D**
Newcomb, Prof. S., Navy Dep't, Washington, D. C. (13). 1874. **A B**
Newell, F. H., U. S. Geol. Survey, Washington, D. C. (40). 1893.
Newell, William Wells, Editor Journal American Folk Lore, Cambridge, Mass. (41). 1893. **H**
Newton, Hubert A., New Haven, Conn. (6). 1874. **A**
Nichols, Ernest Fox, Hamilton, N. Y. (41). 1893. **B**
Nichols, E. L., Ph.D., Cornell Univ., Ithaca, N. Y. (28). 1881. **B C**
Nicholson, Prof. H. H., Box 675, Lincoln, Neb. (36). 1888.
Niles, Prof. W. H., Cambridge, Mass. (16). 1874.
Nipher, Prof. F. E., Washington Univ., St. Louis, Mo. (24). 1876. **B**
Nolan, Edw. J., M.D., Academy of Natural Sciences, Philadelphia, Pa. (29). 1890. **F**
NORTON, PROF. THOMAS H., Univ. of Cincinnati, Cincinnati, Ohio (35). 1887. **C**
Noyes, Prof. Wm. A., Rose Polytechnic Inst., Terre Haute, Ind. (32). 1885. **C**
Nuttall, Mrs. Zella, care Peabody Museum, Cambridge, Mass. (35). 1887. **H**

Nutting, Prof. Charles C., State Univ. of Iowa, Iowa City, Iowa (40). 1892. F

Ogden, Herbert G., U. S. Coast and G. Survey, Washington, D. C. (38). 1891. E
Oliver, Prof. James E., 7 Central Ave., Ithaca, N. Y. (7). 1875. A B I
Ordway, Prof. John M., Tulane Univ., New Orleans, La. (9). 1875. C
Orndorff, Dr. William Ridgely, Cornell Univ., Ithaca, N. Y. (41). 1893. C
Orton, Prof. Edward, President Ohio Agricultural and Mechanical College, Columbus, Ohio (19). 1875. E
Osborn, Henry F., Columbia College, New York, N. Y. (29). 1883. F
Osborn, Herbert, Ames, Iowa (32). 1884. F
Osmond, Prof. I. Thornton, State College, Centre Co., Pa. (33). 1889. B A C

Packard, Dr. A. S., 115 Angell St., Providence, R. I. (16). 1875. F E
Paine, Cyrus F., 305 Ellwanger & Barry Building, Rochester, N. Y. (12). 1874. B A
Palfray, Hon. Charles W., Salem, Mass. (21). 1874.
Pammel, Prof. L. H., Iowa Agricultural College, Ames, Iowa (39). 1892.
Parke, John G., Gen. U. S. A., 16 Lafayette Square, Washington, D. C. (29). 1881. D
Parkhurst, Henry M., 173 Gates Ave., Brooklyn, N. Y. (23). 1874. A
Patrick, Geo. E., Ames, Iowa (36). 1890. C
Patterson, Harry J., College Park, Prince George's Co., Md. (36). 1890. C
Paul, Prof. Henry M., U. S. Naval Observatory, Washington, D. C. (33). 1885. A B
Peabody, Selim H., 4200 Berkeley Ave., Chicago, Ill. (17). 1885. D B F
Peary, Robert E., C.E., U. S. N., United States Navy Yard, League Island, Philadelphia, Pa. (36). 1892. D
Pedrick, Wm. R., Lawrence, Mass. (22). 1875.
Peet, Rev. Stephen D., Avon, Ill. (24). 1881. H
Penrose, Dr. R. A. F., 1331 Spruce St., Philadelphia, Pa. (38). 1890. E
Perkins, Prof. George H., Burlington, Vt. (17). 1882. H F E
Peter, Dr. Robert, Kentucky Geol. Survey, Lexington, Ky. (29). 1881. C
Peters, Edw. T., P. O. Box 265, Washington, D. C. (33). 1889. I
Pettee, Prof. William H., 52 Thompson St., Ann Arbor, Mich. (24). 1875 E
Phillips, Prof. A. W., New Haven, Conn. (24). 1879.
Phillips, Prof. Francis C., 59 Sherman Ave., Allegheny, Pa. (36). 1889. C
Phillips, Henry, jr., 1811 Walnut St., Philadelphia, Pa. (32). 1887. H I
Phippen, Geo. D., Salem, Mass. (18). 1874. G
Pickering, Prof. E. C., Director of Observatory, Cambridge, Mass. (18). 1875. A B
Pilling, James C., Box 591, Washington, D. C. (28). 1882. F H I
Platt, Franklin, Ass't Geologist, 2nd Geol. Survey of Pa., 1319 Walnut St., Philadelphia, Pa. (27). 1882. E
Pohlman, Dr. Julius, Buffalo, N. Y. (32). 1884. E F

Porter, Thos. C., LL.D., Lafayette College, Easton, Pa. (33). 1887. G
Powell, Major J. W., Washington, D. C. (23). 1875. E H
Power, Prof. Frederick B., 225 Gregory Ave., Passaic, N. J. (31) 1887. C
Prentiss, Prof. A. N., Cornell Univ., Ithaca, N. Y. (35). 1887. G
Prentiss, D. Webster, M.D., 1101 14th St., N. W., Washington, D. C. (29). 1882. F
Prentiss, Robert W., Prof. of Mathematics and Astronomy, Rutgers College, New Brunswick, N. J. (40). 1891. A
Prescott, Prof. Albert B., Ann Arbor, Mich. (23). 1875. C
Prosser, Charles S., Prof. of Geology, Union Coll., Schenectady, N. Y. (33). 1891. E F
Pulsifer, Wm. H., Newton Centre, Mass. (26). 1879. A H
Pumpelly, Prof. Raphael, U. S. Geological Survey, Newport, R. I. (17). 1875. E I
Putnam, Prof. F. W., Curator Peabody Museum American Archæology and Ethnology, Cambridge, Mass. (Address as Permanent Secretary A. A. A. S., Salem, Mass.) (10). 1874. H

Rathbun, Richard, U. S. National Museum, Washington, D. C. (40). 1892. F
Rau, Eugene A., Bethlehem, Pa. (33). 1890. G
Raymond, Rossiter W., 13 Burling Slip, New York, N. Y. (15). 1875. E I
Redfield, J. H., 216 W. Logan Square, Philadelphia, Pa. (1). 1874. G
Rees, Prof. John K., Columbia College, New York, N. Y. (26). 1878. A E B
Reese, Charles L., The Citadel, Charleston, S. C. (39). 1892. C
Reese, Jacob, 400 Chestnut St., Philadelphia, Pa. (33). 1891. D B
Reid, Harry Fielding, Case School of Applied Science, Cleveland, Ohio, (36). 1893. B
Remsen, Prof. Ira, Johns Hopkins Univ., Baltimore, Md. (22). 1875. C
Rice, Prof. Wm. North, Wesleyan University, Middletown, Conn. (18). 1874. E F
Richards, Prof. Charles B., 137 Edwards St., New Haven, Conn. (33). 1885. D
Richards, Edgar, 1621 H St., Washington, D. C. (31). 1886. C
Richards, Prof. Robert H., Mass. Inst. Tech., Back Bay, Boston, Mass. (22). 1875. D
Richards, Mrs. Robert H., Prof. Mass. Inst. of Tech., Back Bay, Boston, Mass. (23). 1878. C
Richardson, Clifford, Central Power Station, W. & G. R. R. Co., 14th St. and Penn. Ave., Washington, D. C. (30). 1884. C
Ricketts, Prof. Palmer C., 17 1st St., Troy, N. Y. (33). 1887. D A
Ricketts, Prof. Pierre de Peyster, 104 John St., New York, N. Y. (26). 1880. C D E
Riley, Prof. C. V., Hon. Curator of Entomology, U. S. National Museum, Washington, D. C. (17). 1874. F H I

Risteen, Allen D., Hartford, Conn. (38). 1890. **A B D**
Ritchie, E. S., Newton Highlands, Mass. (10). 1877. **B**
Ritter, W. F. McK., P. O. Box 50. Milton, Pa. (40). 1893.
Robinson, Benjamin Lincoln, Curator Harvard Herbarium, Cambridge, Mass. (41). 1893. **G**
Robinson, Prof. Franklin C., Bowdoin College, Brunswick, Me. (29). 1889. **C D**
Robinson, Prof. S. W., 1353 Highland St., Columbus, Ohio (30). 1888. **D B A**
Rockwell, Gen. Alfred P., Manchester, Mass. (10). 1882. **E**
Rockwell, Chas. H., Box 293, Tarrytown, N. Y. (28). 1883. **A D**
Rockwood, Prof. Charles G., jr., College of New Jersey, Princeton, N. J. (20). 1874. **A E B D**
Rogers, Prof. W. A., Colby Univ., Waterville, Me. (15). 1875. **A B D**
Rominger, Dr. Carl, Ann Arbor, Mich. (21). 1879. **E**
Rood, Prof. O. N., Columbia College, New York, N. Y. (14). 1875. **B**
Rosa, Edward Bennett, Prof. of Physics, Wesleyan Univ., Middletown, Conn. (39). 1892. **A B**
Ross, Prof. Edward A., Cornell Univ., Ithaca, N. Y. (41). 1894. **I**
Ross, Waldo O., 1 Chestnut St., Boston, Mass. (29). 1882.
Rowland, Prof. Henry A., Baltimore, Md. (29). 1880. **B**
Runkle, Prof. J. D., Mass. Institute of Technology, Boston, Mass. (2). 1875. **A D**
Rusby, Henry H., M.D., College of Pharmacy, 211 E. 23d St., New York, N. Y. (36). 1890. **G**
Russell, H. L., Ph.D., Madison, Wis. (41). 1894.
Russell, I. C., Univ. of Mich., Ann Arbor, Mich. (25). 1882. **E**
Ryan, Harris J., Cornell Univ., Ithaca, N. Y. (38). 1890. **B**

Saegmuller, G. N., 132 Maryland Ave., S. W., Washington, D. C. (38). 1891. **A B**
Safford, Dr. James M., Nashville, Tenn. (6). 1875. **E C F**
Safford, Prof. Truman H., Williamstown, Mass. (41). 1892. **A**
Salisbury, Prof. R. D., Chicago Univ., Chicago, Ill. (37). 1890. **B E**
Salmon, Daniel E., Dep't of Agric., Washington, D. C. (31). 1885. **F**
Sampson, Commander W. T., U. S. N., Navy Dept., Washington, D. C. (25). 1881. **B A**
Saunders, William, Director Canadian Experimental Farms, Ottawa, Ontario, Can. (17). 1874. **F**
Saville, Marshall H., Amer. Mus. Nat. Hist., Central Park, New York, N. Y. (39). 1892. **H**
Schaeberle, J. M., Astronomer in the Lick Observatory, San José, Cal. (34). 1886. **A**
Schanck, Prof. J. Stillwell, Princeton, New Jersey (4). 1882. **C B H**
Schott, Charles A., U. S. Coast and Geodetic Survey Office, Washington, D. C. (8). 1874. **A**
Schweinitz, Dr. E. A. de, Dep't of Agriculture, Washington, D. C. (36). 1889. **C**

Schweitzer, Prof. Paul, State University of Missouri, Columbia, Mo. (24). 1877. **C B**

Scovell, M. A., Director Kentucky Agricultural Experiment Station, Lexington, Ky. (35). 1887.

Scribner, F. Lamson, Director Tenn. Agricultural Exper. Station, Knoxville, Tenn. (34). 1887. **G**

SCUDDER, SAMUEL H., Cambridge, Mass. (13). 1874. **F**

Seaman, W. H., Chemist, 1424 11th St. N. W., Washington, D. C. (23). 1874. **C F**

Searle, Prof. Geo. M., Catholic Univ., Washington, D. C. (39). 1891. **A**

See, Horace, 1 Broadway, New York, N. Y. (34). 1886. **D**

Seller, Carl, M.D., 1346 Spruce St., Philadelphia, Pa. (29). 1882. **F B**

Seymour, Arthur Bliss, Cambridge, Mass. (36). 1890. **G**

Sharples, Stephen P., 13 Broad St., Boston, Mass. (29). 1884. **C**

Sheldon, Samuel, A.M., Ph.D., Polytechnic Inst., Brooklyn, N. Y. (42). 1894. **B**

Shelton, Prof. Edward M., Dep't of Agric., Brisbane, Queensland, Australia (32). 1892. **F**

Shimer, Porter W., E.M., Easton, Pa. (38). 1889. **C**

Shufeldt, Dr. R. W., Smithsonian Institution, Washington, D. C. (40). 1892. **F**

Shutt, Frank T., M.A., F.E.C., F.C.S., Chief Chemist Canadian Experimental Farm, Ottawa, Ontario, Can. (38). 1889. **C**

Sias, Solomon, M.D., Schoharie, Schoharie Co., N. Y. (10). 1874.

Sigsbee, Chas. D., Com'd'r U. S. N., U. S. Hydrographic Office, Washington, D. C. (28). 1882. **D E**

Silliman, Prof. Justus M., Lafayette Coll., Easton, Pa. (19). 1874. **D E**

Skinner, Aaron N., U. S. Naval Observ., Washington, D. C. (40). 1893. **A**

Skinner, Joseph J., Massachusetts Inst. Technology, Boston, Mass. (23). 1880. **B**

Smith, Alex., Ph.D., Wabash College, Crawfordsville, Ind. (40). 1892. **C**

Smith, Prof. Chas. J., 35 Adelbert St., Cleveland, Ohio (32). 1885. **A B**

Smith, Prof. Edgar F., Univ. of Penn., Philadelphia, Pa. (33). 1891. **C**

Smith, Edwin, Ass't U. S. Coast and Geodetic Survey, Washington, D. C. (30). 1882. **A B**

Smith, Prof. Erastus G., Beloit College, Beloit, Wis. (34). 1887. **C**

Smith, Erwin F., Dep't of Agric., Washington, D. C. (34). 1890. **G**

Smith, Prof. Eugene A., University, Ala. (20). 1877. **E C**

Smith, James Perrin, Ph.D., Ass't Prof. of Paleontology, Leland Stanford Junior Univ., Palo Alto, Cal. (37). 1894. **C E**

Smith, John B., Professor of Entomology, Rutgers College, New Brunswick, N. J. (32). 1884. **F**

SMITH, QUINTUS C., M.D., No. 617 Colo. St., Austin, Texas (26). 1881. **F**

Smith, Dr. Theobald, Bureau of Animal Industry, U. S. Dep't of Agric., Washington, D. C. (35). 1887. **F**

Sn ock, Prof. John Conover, Trenton, N. J. (23). 1879. **E**

Smyth, C. H., jr., Clinton, N. Y. (38). 1894. **E**
Snow, Prof. Benj. W., Madison, Wis. (35). 1889. **B**
Snow, Julia W., La Salle, Ill. (39). 1892. **F**
Snyder, Henry, B.Sc., Miami Univ., Oxford, Ohio (30). 1888. **B C**
Snyder, Prof. Monroe B., High School Observatory, Philadelphia, Pa. (24). 1882. **A B**
Soule, R. H, Roanoke, Va. (33). 1886. **D**
Spencer, Prof. J. William (28). 1882. **E**
Springer, Dr. Alfred, Box 621, Cincinnati, Ohio (24). 1880. **C**
Starr, Frederick, Ph.D., Prof. Univ. of Chicago, Chicago, Ill. (36). 1892. **H E**
Stearns, R. E. C., care Smithsonian Institution, Washington, D. C. (18). 1874. **F**
Stedman, Prof. John M., A. and M. Coll., Auburn, Ala. (40). 1892. **F**
Stejneger, Leonhard, Curator Dept. of Reptiles, National Museum, Washington, D. C. (40). 1892. **F**
Stephens, W. Hudson, Lowville, N. Y. (18). 1874. **E H**
Sternberg, Col. George M., Surgeon U. S. A., Army Building, 39 Whitehall St., New York, N. Y. (24). 1880. **F**
Stevens, Prof. W. LeConte, Rensselaer Polytechnic Inst., Troy, N. Y. (29). 1882. **B A C**
Stevenson, Prof. John J., Univ. of New York, New York, N. Y. (36). 1888.
Stevenson, Mrs. Matilda C., Bureau of Ethnology, Washington, D. C. (41). 1893. **H**
Stiles, Dr. Chas. W., Dept. of Agric., Washington, D. C. (40). 1892. **F**
Stokes, Henry Newlin, Ph.D., U. S. Geol. Survey, Washington, D. C. (38). 1891. **C E**
Stone, Ormond, Director Leander McCormick Observatory, University of Virginia, Va. (24). 1876. **A**
Stone, Prof. Winthrop E., Purdue Univ., La Fayette, Ind. (39). 1891. **C**
Story, Prof. Wm E., Clark Univ., Worcester, Mass. (29). 1881. **A**
Stowell, Prof. T. B., Potsdam, N. Y. (28). 1885. **F**
Stuart, Prof. A. P. S., Lincoln, Nebraska (21). 1874. **C**
Sturgis, Wm. C., 384 Whitney Ave., New Haven, Conn. (40). 1892. **G**
Sturtevant, E. Lewis, M.D., So. Framingham, Mass. (29). 1882. **G**
Swift, Lewis, Ph.D., Warner Observatory, Rochester, N. Y. (29). 1882. **A**
Swingle, W. T., Eustis, Florida (40). 1892. **G**

Tainter, Charles Sumner, 1843 S, cor. 19th St., Washington, D. C. (29). 1881. **B D A**
Taylor, Thos., M.D., Department of Agriculture, Washington, D. C. (29). 1885. **F C**
Taylor, William B., Smithsonian Institution, Washington, D. C. (29). 1881. **B A**
Terry, Prof. N. M., U. S. Naval Acad, Annapolis, Md. (23). 1874. **B**
Thomas, Benj. F., Ph.D., State Univ., Columbus, Ohio (29). 1882. **B A**
Thomas, Prof. M. B., Crawfordsville, Ind. (41). 1894. **G**

Thompson, Joseph Osgood, Haverford College, Pa. (41). 1893.
Thomson, Elihu, Thomson-Houston Electric Co., Lynn, Mass. (37). 1888. **B**
Thomson, Wm., M.D., 1426 Walnut St., Philadelphia, Pa. (33). 1885. **B**
Thruston, Gates Phillips, Nashville, Tenn. (38). 1890. **H**
Thurston, Prof. R. H., Sibley College, Cornell University, Ithaca, N. Y. (23). 1875. **D**
Thwing, Charles B., Northwestern Univ., Evanston, Ill. (38). 1892. **B**
Tittmann, Otto H., U. S. Coast and Geodetic Survey Office, Washington, D. C. (24). 1888. **A**
Todd, Prof. James E., Vermillion, So. Dak. (22). 1886. **E F**
Townshend, Prof. N. S., Ohio State Univ., Columbus, Ohio (17). 1881. **F H**
Tracy, Sam'l M., Agricultural College, Miss. (27). 1881. **G**
Traphagen, Frank W., Ph.D., Bozeman, Montana (35). 1889. **C F E**
Trelease, Dr. Wm., Director Missouri Botanical Gardens, St. Louis, Mo. (39). 1891. **G**
Trimble, Prof. Henry, 145 No. 10th St., Philadelphia, Pa. (34). 1889. **C**
Trumbull, Dr. J. Hammond, Hartford, Conn. (29). 1882. **H**
Tucker, Willis G., M.D., Albany Med. Coll., Albany, N. Y. (29). 1888. **C**
Tuckerman, Alfred, Ph.D., 342 W. 57th St., New York, N. Y. (39). 1891. **C**
Tuttle, Prof. Albert H., Univ. of Virginia, Charlottesville, Va. (17). 1874. **F**
Twitchell, E., 10 Bellevue Ave., Mt. Auburn, Cincinnati, Ohio (39). 1891. **C**

Uhler, Philip R., 254 W. Hoffman St., Baltimore, Md. (19). 1874. **F E**
Uline, Edwin Burton, Lake Forest, Ill. (42). 1894. **G**
Underwood, Prof. Lucien M., De Pauw Univ., Greencastle, Ind. (33). 1885. **G**
Upham, Warren, 36 Newbury St., Somerville, Mass. (25). 1880. **E**
Upton, Winslow, Brown Univ., Providence, R. I. (29). 1883. **A**

Van der Weyde, P. H., M.D., 40 E. 7th St., New York, N. Y. (17). 1874. **B**
Van Dyck, Prof. Francis Cuyler, New Brunswick, N. J. (28). 1882. **B C F**
Van Hise, Charles R., Univ. of Wisconsin, Madison, Wis. (37). 1890.
Van Vleck, Prof. John M., Wesleyan Univ., Middletown, Conn. (23). 1875. **A**
Venable, Prof. F. P., Chapel Hill, N. C. (39). 1891. **C**
Vining, Edward P., care Chas. B. Griggs, Washington St., Brookline, Mass. (32). 1887. **H**
Vogdes, A. W., Capt. 5th Art'y, Alcatraz Island, San Francisco, Cal. (32). 1885. **E F**

Wadsworth, Prof. M. Edward, Ph D., Director of the Michigan Mining School, State Geologist of Michigan, Houghton, Mich. (23). 1874. **E**

Waite, M. B., Dep't of Agric., Washington, D. C. (37). 1893. G
Walcott, Charles D., Director U. S. Geological Survey, Washington, D. C. (25). 1882. E F
Waldo, Prof., Clarence A., Greencastle, Ind. (37). 1889. A
Waldo, Leonard, S. D., Bridgeport, Conn. (28). 1880. A
Wallace, Wm., Ansonia, Conn. (28). 1882.
WALLER, E., School of Mines, Columbia College, New York, N. Y. (28). 1874.
Walmsley, W. H., 69 Washington St., Chicago, Ill. (28). 1883. F
Ward, Prof. Henry A., Rochester, N. Y. (13). 1875. F E H
Ward, Lester F., U. S. Geological Survey, Washington, D. C. (26). 1879. E G
Ward, Dr. R. H., 53 Fourth St., Troy, N. Y. (17). 1874. G F
Ward, Wm. E., Port Chester, N. Y. (36). 1889. D
Warder, Prof. Robert B., Howard Univ., Washington, D. C. (19). 1881. C B
Warner, Prof. A. G., Leland Stanford jr. Univ., Palo Alto, Cal. (38). 1892. I
WARNER, JAMES D., 199 Baltic St., Brooklyn, N. Y. (18). 1874. A B
Warner, Worcester R., 887 Case Ave., Cleveland, Ohio (33). 1888. A B D
Warren, Dr. Joseph W., Bryn Mawr Coll., Bryn Mawr, Pa. (31). 1886. F
Warren, Prof. S. Edward, Newton, Mass. (17). 1875. A–I
WATSON, PROF WM., 107 Marlborough St., Boston, Mass. (12). 1884. A
Webb, Prof. J. Burkitt, Stevens Inst., Hoboken, N. J. (31). 1883. D B A
Weber, Prof. Henry A., Ohio State Univ., Columbus, Ohio (35). 1888. F
Webster, F. M., Wooster, Ohio (35). 1890. F
Webster, Prof. N. B., Vineland, N. J. (7). 1874. B C E
Weed, Clarence M., Durham, N. H. (38). 1890.
Wheeler, Prof. C. Gilbert, 143 Lake St., Chicago, Ill. (18). 1883. C E
Wheeler, Orlando B., Office Mo. River Com., 1515 Lucas Place, St. Louis, Mo. (24). 1882. A D
White, Prof. C. A., Le Droit Park, Washington, D. C. (17). 1875. E F
White, David, U. S. National Museum, Washington, D. C. (40). 1892. E F
White, Prof. H. C., Univ. of Georgia, Athens, Ga. (29). 1885. C
WHITE, PROF. I. C., Univ. of W. Va., Morgantown, W. Va. (25). 1882. E
Whiteaves, J. F., Geol. Survey, Ottawa, Ontario, Can. (31). 1887. E F
Whitfield, R. P., American Museum Natural History, 77th St. and 8th Avenue, New York, N. Y. (18). 1874. E F H
Whiting, Miss Sarah F., Wellesley College, Wellesley, Mass. (31). 1883. B A
Whitman, Prof. Frank P., Adelbert College, Cleveland, Ohio (33). 1885. A B
Wilbur, A. B., Middletown, N. Y. (23). 1874. E
Wiley, Prof. Harvey W., Dep't of Agric., Washington, D.C. (21). 1874. C
Williams, Benezette, 171 La Salle St., Chicago, Ill. (33). 1887. D

Williams, Charles H., M.D., C. B. and Q. Gen. Office, Adams St., Chicago, Ill. (22). 1874.
Williams, Prof. Edw. H., jr., 117 Church St., Bethlehem, Pa. (25). 1894. **E D**
Williams, Prof. Henry Shaler, Yale College, New Haven, Conn. (18). 1882. **E F**
Williams, Prof. Henry W., 15 Arlington St., Boston, Mass. (11). 1874. **H F**
Williams, Prof. Thos. A., Agricultural Coll., Brookings, So. Dak. (42). 1894. **G**
Willson, Prof. Frederick N., Princeton, N. J. (33). 1887. **A D**
Willson, Robert W., Cambridge, Mass. (30). 1890. **B A**
Wilson, Joseph M., Room 1036, Drexel Building, Philadelphia, Pa. (33). 1886. **D**
Wilson, Thomas, U. S. Nat'l Museum, Washington, D. C. (36). 1888. **H**
Wilson, Prof. William Powell, Dept. of Biology, Univ. of Pa., Philadelphia, Pa. (38). 1889. **G**
Winchell, Horace V., 1306 S. E. 7th St., Minneapolis, Minn. (34). 1890. **E C**
Winchell, Prof. N. H., Univ. of Minnesota, Minneapolis, Minn. (19). 1874. **E H**
Wing, Henry H., 3 Reservoir Ave., Ithaca, N. Y. (38). 1890.
Winlock, Wm. C., Smithsonian Institution, Washington, D. C. (33). 1885. **A B**
Winslow, Arthur, Geologist and Mining Expert, Rooms 411 and 412, Roe Building, 5th and Pine Sts., St. Louis, Mo. (37). 1889. **E**
Winterhalter, A. G., Lt. U. S. N., care Navy Dept., Washington, D. C. (37). 1893. **A**
Withers, Prof. W. A., Agric. and Mechanical College, Raleigh, N. C. (33). 1891. **C**
Witthaus, Dr. R. A., 303 W. 77th St., New York, N. Y. (35). 1890.
Wolff, Dr. J. E., 15 Story St., Cambridge, Mass. (36). 1894. **E**
Wood, Prof. De Volson, Hoboken, N. J. (29). 1881.
Woodbury, C. J. H., Amer. Bell Telephone Co., 125 Milk St., Boston, Mass. (29). 1884. **D**
Woodward, R. S., Columbia College, New York, N. Y. (33). 1885. **A B D**
Wormley, T. G., Univ. of Pennsylvania, Philadelphia, Pa. (20). 1878.
Worthen, W. E., 63 Bleeker St., New York, N. Y. (36). 1888. **D**
Wrampelmeier, Theo. J., Room 17, Appraiser's Building, San Francisco, Cal. (34). 1887. **C**
Wright, Prof. Albert A., Oberlin College, Oberlin, Ohio (24). 1880. **E F**
Wright, Prof. Arthur W., Yale Coll., New Haven. Conn. (14). 1874. **A B**
Wright, Carroll D., LL.D., Dep't of Labor, Washington, D. C. (41). 1894. **I**
Wright, Rev. Geo. F., Oberlin College, Oberlin, Ohio (29). 1882. **E**
Wright, Prof. Thos. W., Union College, Schenectady, N. Y. (36). 1889.
Würtele, Rev. Louis C., Acton Vale, P. Q., Can. (11). 1875. **E**

Youmans, Wm. Jay, M.D., Popular Science Monthly, 1–5 Bond St., New York, N. Y. (28). 1889. **F C**

Young, A. V. E., Northwestern Univ., Evanston, Ill. (33). 1886. **C B**

Young, C. A., Prof. of Astronomy, College of New Jersey, Princeton, N. J. (18). 1874. **A B D**

Ziwet, Alexander, 44 Madison St., Ann Arbor, Mich. (38). 1890. **A**

[756 FELLOWS.]

SUMMARY.—PATRONS, 2; CORRESPONDING MEMBERS, 2; MEMBERS, 1042; HONORARY FELLOWS, 1; FELLOWS, 755.

DEC. 31, 1894, TOTAL NUMBER OF MEMBERS OF THE ASSOCIATION, 1802.

DECEASED MEMBERS.

[Unless by special vote of the Council, the names of those only who are members of the Association at the *time of their decease* will be included in this list. Information of the date and place of birth and death, to fill blanks in this list, is requested by the Permanent Secretary.]

Abbe, George Waldo, New York, N. Y. (23). Born in Windham, Conn. Oct. 26, 1811. Died in New York, N. Y., Sept. 25, 1879.

Abert, John James, Washington, D. C. (1). Born in Shepherdstown, Va., Sept. 17, 1788. Died in Washington, D. C., Sept. 27, 1863.

Adams, Charles Baker, Amherst, Mass. (1). Born in Dorchester, Mass., Jan. 11, 1814. Died in St. Thomas, W. I., Jan. 19, 1853.

Adams, Edwin F., Charlestown, Mass. (18).

Adams, Samuel, Jacksonville, Ill. (18). Born Dec. 19, 1806. Died April 29, 1877.

Agassiz, Louis, Cambridge, Mass. (1). Born in Parish of Motier, Switzerland, May 28, 1807. Died in Cambridge, Mass., Dec. 14, 1873.

Ainsworth, J. G., Barre, Mass. (14).

Alexander, Stephen, Princeton, N. J. (1). Born Sept. 1, 1806. Died June 25, 1883.

Allen, Thomas, St. Louis, Mo. (27). Died April 8, 1882.

Allen, Zachariah, Providence, R. I. (1). Born in Providence, R. I., Sept. 15, 1795. Died March 17, 1882.

Allston, Robert Francis Withers, Georgetown, S. C. (3). Born in All Saints Parish, S. C., April 21, 1801. Died near Georgetown, S. C., April 7, 1864.

Alvord, Benjamin, Washington, D. C. (17). Born in Rutland, Vt., Aug. 18, 1813. Died Oct. 16, 1884.

Ames, Nathan P., Springfield, Mass. (1). Born in 1803. Died Apr. 23, 1847.

Andrews, Ebenezer Baldwin, Lancaster, Ohio (7). Born in Danbury, Conn., April 29, 1821. Died in Lancaster, Ohio, Aug. 14, 1880.

Anthony, Charles H., Albany, N. Y. (6). Died in 1874.

Antisell, Thomas, Washington, D. C. (33).

Appleton, Nathan, Boston, Mass. (1). Born in New Ipswich, N. H., Oct. 6, 1779. Died July 14, 1861.

Armstrong, John W., Fredonia, N. Y. (24).

Ashburner, Charles A., Pittsburgh, Pa. (31). Died Dec. 24, 1889.

Ashburner, Wm., San Francisco, Cal. (29). Born in Stockbridge, Mass., March. 1831. Died in San Francisco, Cal., April 20, 1887.

Atwater, Mrs. S. T., Chicago, Ill. (17). Born Aug. 8, 1812. Died April 11, 1878.

Aufrecht, Louis, Cincinnati, Ohio (30).

Baba, Tatui, New York, N. Y. (36).

Babbitt, Miss Franc E., Coldwater, Mich. (32). Died near Coldwater, Mich., July 6, 1891, aged 67.

Bache, Alexander Dallas, Washington, D. C. (1). Born in Philadelphia, Pa., July 19, 1806. Died at Newport, R. I., Feb. 17, 1867.

Bache, Franklin, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Oct. 25, 1792. Died March 19, 1864.

Bailey, Jacob Whitman, West Point, N. Y. (1). Born in Auburn, Mass., April 29, 1811. Died in West Point, N. Y., Feb. 26, 1857.

Baird, Spencer Fullerton, Washington, D. C. (1). Born in Reading, Pa., Feb. 3, 1823. Died in Wood's Holl, Mass., Aug. 19, 1887.

Bardwell, F. W., Lawrence, Kan. (13). Died in 1878.

Barnard, F. A. P., New York, N. Y. (7). Born in Sheffield, Mass., May 5, 1809. Died in New York, April 27, 1889.

Barnard, John Gross, New York, N. Y. (14). Born in Sheffield, Mass., May 19, 1815. Died in Detroit, Mich., May 14, 1882.

Barrett, Dwight H., Baltimore, Md. (36). Died in March, 1889.

Barrett, Moses, Milwaukee, Wis. (21). Died in 1873.

Barry, Redmond, Melbourne, Australia (25).

Bassett, Daniel A., Los Angeles, Cal. (29). Born Dec. 8, 1819. Died May 26, 1887.

Bassnett, Thomas, Jacksonville, Fla. (8). Born 1807. Died in Jacksonville, Fla., Feb. 16, 1886.

Batchelder, John Montgomery, Cambridge, Mass. (8). Born in New Ipswich, N. H., Oct. 13, 1811. Died in Cambridge, July 3, 1892.

Bayne, Herbert Andrew, Kingston, Ont., Can. (29). Born in Londonderry, Nova Scotia, Aug. 16, 1846. Died in Pictou, Can., Sept. 16, 1886.

Beach, J. Watson, Hartford, Conn. (23). Born Dec. 28, 1823. Died Mar. 16, 1887.

Beauregard, Gustave T., New Orleans, La. (30). Died Feb. 20, 1893, aged 75.

Beck, C. F., Philadelphia, Pa. (1).

Beck, Lewis Caleb, New Brunswick, N. J. (1). Born in Schenectady, N. Y., Oct. 4, 1798. Died April 20, 1853.

Beck, Theodoric Romeyn, Albany, N. Y. (1). Born in Schenectady, N. Y., Aug. 11, 1791. Died in Utica, N. Y., Nov. 19, 1855.

Beckwith, Henry C., Coleman's Station, N. Y. (29). Died July 12, 1885.

Belfrage, G. W., Clifton, Texas (29). Died Dec. 7, 1882.

Belknap, William B., Louisville, Ky. (29).

Bell, Samuel N., Manchester, N. H. (7). Born in Chester, N. H., March 25, 1829. Died in Manchester, N. H., Feb. 8, 1889.

Belt, Thomas, London, Eng. (27). Died Sept. 8, 1878.

Benedict, George Wyllys, Burlington, Vt. (16). Born Jan. 11, 1796. Died Sept. 23, 1871.

Benjamin, Edmund Burke, New York, N. Y. (19). Born in East Bloomfield, N. Y., July 16, 1828. Died in New York, May 29, 1894.

Bicknell, Edwin, Boston, Mass. (18). Born in 1830. Died March 19, 1877.

Binney, Amos, Boston, Mass. (1). Born in Boston, Mass., Oct. 18, 1803. Died in Rome, Feb. 18, 1847.

Binney, John, Boston, Mass. (3).

Blackie, Geo. S., Nashville, Tenn. (26).
Blair, Henry W., Washington, D. C. (26). Died Dec. 15, 1884.
Blake, Eli Whitney, New Haven, Conn. (1). Born Jan. 27, 1795. Died Aug. 18, 1886.
Blake, Francis C., Mansfield Valley, Pa. (29). Died Feb. 21, 1891.
Blake, Homer Crane, New York, N. Y. (28). Born in Cleveland, Ohio, Feb. 1, 1822. Died in New York, N. Y., Jan. 20, 1880.
Blanding, William, ———, R. I. (1).
Blatchford, Thomas W., Troy, N. Y. (6).
Blatchley, Miss S. L., New Haven, Conn. (19). Died March 13, 1873.
Boadle, John, Haddonfield, N. J. (20). Born in 1805. Died in July, 1878.
Bomford, George, Washington, D. C. (1) Born in New York, N. Y., 1780. Died in Boston, Mass., March 25, 1848.
Bowditch, Henry Ingersoll, Boston, Mass. (2). Born in Salem, Mass., Aug. 9, 1808. Died in Boston, Mass., Jan. 14, 1892.
Bowles, Miss Margaretta, Columbia, Tenn. (26). Died July, 1887.
Bowron, James, South Pittsburg, Tenn. (26). Died in Dec., 1877.
Bradley, Leverette, Jersey City, N. J. (15). Died in 1875.
Braithwaite, Jos., Chambly, C. W. (11).
Breckinridge, S. M., St. Louis, Mo. (27). Died May 28, 1891.
Briggs, Albert D., Springfield, Mass. (13). Died Feb. 20, 1881.
Briggs, Robert, Philadelphia, Pa. (29). Born May 18, 1822. Died July 24, 1882.
Brigham, Charles Henry, Ann Arbor, Mich. (17). Born in Boston, Mass., July 27, 1820. Died Feb. 19, 1879.
Bronson, Henry, New Haven, Conn. (41). Born in Waterbury, Conn., Jan. 30, 1804. Died in New Haven, Nov. 26, 1893.
Bross, William, Chicago, Ill. (7). Died in 1890.
Brown, Andrew, Natchez, Miss. (1).
Brown, Horace, Salem, Mass. (27). Died in July, 1883.
Bull, John, Washington, D. C. (31). Born Aug. 1, 1819. Died June 9, 1884.
Bulloch, Walter H., Chicago, Ill. (30).
Burbank, L. S., Woburn, Mass. (18).
Burgess, Edward, Boston, Mass. (22). Born in Barnstable, Mass., June 30, 1848. Died in Boston, July 12, 1891.
Burke, Joseph Chester, Middletown, Conn. (29). Died in 1885.
Burnap, George Washington, Baltimore, Md. (12). Born in Merrimack, N. H., Nov. 30, 1802. Died in Philadelphia, Pa., Sept. 8, 1859.
Burnett, Waldo Irving, Boston, Mass. (1). Born in Southborough, Mass., July 12, 1828. Died in Boston, Mass., July 1, 1854.
Butler, Thomas Belden, Norwalk, Conn. (10). Born Aug. 22, 1806. Died June 8, 1878.

Cairns, Frederick A., New York, N. Y. (27). Died in 1879.
Campbell, Mrs. Mary H., Crawfordsville, Ind. (22). Died Feb. 27, 1882
Carpenter, Thornton, Camden, S. C. (7).
Carpenter, William M., New Orleans, La. (1).

Case, Leonard, Cleveland, Ohio (15). Born June 27, 1820. Died Jan. 5, 1880.

Case, William, Cleveland, Ohio (6).

Caswell, Alexis, Providence, R. I. (2). Born Jan. 29, 1799. Died in Providence, R. I., Jan. 8. 1877.

Chadbourne, Paul Ansel, Amherst, Mass. (10). Born in North Berwick, Me., Oct. 21, 1823. Died Feb. 28, 1883.

Chapin, J. H., Meriden, Conn. (33). Died in 1892.

Chapman, Nathaniel, Philadelphia, Pa. (1). Born in Alexandria Co., Va., May 28, 1780. Died July 1, 1853.

Chase, Pliny Earle, Haverford College, Pa. (18). Born in Worcester, Mass., Aug. 18, 1820.

Chase, Stephen, Hanover, N. H. (2). Born in 1813. Died Aug. 5, 1851.

Chauvenet, William, St. Louis, Mo. (1). Born May 24, 1819. Died Dec. 13, 1870.

Cheesman, Louis Montgomery, Hartford, Conn. (32). Born in 1858. Died in Jan., 1885.

Cheney, Miss Margaret S., Jamaica Plain, Mass. (29). Died in 1882.

Chevreul, Michel Eugène, Paris, France (35). Born in Angiers, France, Aug. 31, 1786. Died April 9, 1889.

Clapp, Asahel, New Albany, Ind. (1). Born Oct. 5, 1792. Died Dec. 15, 1862.

Clark, Henry James, Cambridge, Mass. (13). Born in Easton, Mass. June 22, 1826. Died in Amherst, Mass., July 1, 1873.

Clark, Joseph, Cincinnati Ohio (5).

Clark, Patrick, Rahway, N. J. (33). Died March 5, 1887.

Clarke, A. B., Holyoke, Mass. (13).

Clarke, Charles S., Peoria, Ill. (31). Died Nov. 15, 1890.

Cleaveland, C. H., Cincinnati, Ohio (9).

Cleveland, A. B., Cambridge, Mass. (2).

Coakley, George W., Hempstead, L. I. (29). Born in 1814. Died Aug. 5, 1893.

Coffin, James Henry, Easton, Pa. (1). Born in Northampton, Mass., Sept. 6, 1806. Died Feb. 6, 1873.

Coffin, John H. C., Washington, D. C. (1). Born in Wiscasset, Maine, Sept. 14, 1815. Died in Washington, D. C., Jan. 8, 1890.

Coffinberry, Wright Lewis, Grand Rapids, Mich. (20). Born in Lancaster, Ohio, April 5, 1807. Died in Grand Rapids, Mich., March 26, 1889.

Colburn, E. M., Peoria, Ill. (33). Born in Rome, N. Y., Sept. 13, 1813. Died in Peoria, Ill., May 29, 1890.

Cole, Frederick, Montreal, Can. (31). Died in 1887.

Cole, Thomas, Salem, Mass. (1). Born Dec. 24, 1779. Died June 24, 1852.

Coleman, Henry, Boston, Mass. (1).

Collins, Frederick, Washington, D. C. (28). Born Dec. 5, 1842. Died Oct. 27 1881.

Conrad, Timothy Abbott, Philadelphia, Pa. (1). Born in New Jersey, June 21, 1803. Died Aug. 9, 1877.

Cook, George H., New Brunswick, N. J. (4). Born in Hanover, Morris County, in 1818. Died in New Brunswick, N. J., Sept. 22, 1889.

Cooke, Caleb, Salem, Mass. (18). Born Feb. 15, 1838. Died June 5, 1880.

Cooper, William, Hoboken, N. J. (9). Died in 1864.

Cope, Mary S., Germantown, Pa. (33). Born in Germantown, Pa., July 13, 1853. Died in Germantown, Jan. 4, 1888.

Copes, Joseph S., New Orleans, La. (11). Born Dec. 9, 1811. Died March 1, 1885.

Corning, Erastus, Albany, N. Y. (6). Born in Norwich, Conn., Dec. 14, 1794. Died April 9, 1872.

Costin, M. P., Fordham, N. Y. (30). Died June 8, 1884.

Couper, James Hamilton, Darien, Ga. (1). Born March 5, 1794. Died July 3, 1866.

Coyrière-Pardo, E. Miriam, New York, N. Y. (36). Born in London, Eng., Sept. 2, 1845. Died in New York, N. Y., Feb. 6, 1893.

Cramp, John Mockett, Wolfville, N. S. (11). Born in Kent, England, July 25, 1796. Died Dec. 6, 1881.

Crehore, John D., Cleveland, Ohio (24).

Cresson, Hilborne T., Philadelphia, Pa. (39). Died in New York, N. Y. Sept. 6, 1894.

Crocker, Charles F., Lawrence, Mass. (22). Died in July, 1881.

Crocker, Miss Lucretia, Boston, Mass. (29). Died in 1886.

Crosby, Alpheus, Salem, Mass. (10). Born in Sandwich, N. H., Oct. 13, 1810. Died April 17, 1874.

Crosby, Thomas Russell, Hanover, N. H. (18). Born Oct. 22, 1816. Died March 1, 1872.

Crosier, Edward S., New Albany, Ind. (29). Died in June, 1891.

Croswell, Edwin, Albany, N. Y. (6). Born in Catskill, N. Y., May 29, 1797. Died June 13, 1871.

Crow, Wayman, St. Louis, Mo. (27). Born March 7, 1808. Died May 10, 1885.

Cummings, Joseph, Evanston, Ill. (13). Born in Falmouth, Me., March 3, 1817. Died in Evanston, Ill., May 7, 1890.

Curry, W. F., Geneva, N. Y. (11).

Curtis, George William, Staten Island, N. Y. (36).

Curtis, Josiah, Washington, D. C. (18). Died Aug. 1, 1883.

Cutting, Hiram Adolphus, Lunenburgh, Vt. (17). Born in Concord, Vt., Dec. 23, 1832. Died in Lunenburgh, April 18, 1892.

Da Costa, Chas. M., New York, N. Y. (36). Died in 1890.

Dalrymple, Edwin Augustine, Baltimore, Md. (11). Born in Baltimore, Md., June 4, 1817. Died Oct. 30, 1881.

Danforth, Edward, Elmira, N. Y. (11). Died in Elmira, N. Y., June 13, 1888.

Davenport, H. W., Washington, D. C. (30).

Davis, I. Thomas, Washington, D. C. (40). Died Jan. 19, 1892.

Day, Austin G., New York, N. Y. (29). Died Dec. 28. 1889.

Dayton, Edwin A., Madrid, N. Y. (7). Born in 1827. Died June 24, 1878.

Dean, Amos, Albany, N. Y. (6). Born in Barnard, Vt., Jan. 16, 1803. Died Jan. 26, 1868.

Dearborn, George H. A. S., Roxbury, Mass. (1).

Dekay, James Ellsworth, New York, N. Y. (1). Born in New York, 1792, Died Nov. 21, 1851.

Delano, Joseph C., New Bedford, Mass. (5). Born Jan. 9, 1796. Died Oct. 16, 1886.

De Laski, John, Carver's Harbor, Me. (18).

Devereux, John Henry, Cleveland, Ohio (18). Born in Boston, Mass., April 5, 1832. Died in Cleveland, Ohio, March 17, 1886.

Dewey, Chester, Rochester, N. Y. (1). Born in Sheffield, Mass., Oct. 25, 1781. Died Dec. 15, 1867.

Dexter, G. M., Boston, Mass. (11).

Dickerson, Edward N., New York, N. Y. (36).

Dillingham, W. A P., Augusta, Me. (17).

Dimmick, L. N., Santa Barbara, Cal. (29). Died May 31, 1884.

Dinwiddie, Hardaway H., College Station, Texas (32). Died Dec. 11, 1887.

Dinwiddie, Robert, New York, N. Y. (1). Born in Dumfries, Scotland, July 23. 1811. Died in New York, N. Y., July 12, 1888.

Dixwell, Geo B., Boston, Mass. (29). Died April, 1885.

Doggett, George Newell, Chicago, Ill. (33). Born in Chicago, Ill., Dec. 19, 1858. Died in Fredericksburg, Va., Jan. 15, 1887.

Doggett, Mrs. Kate Newell, Chicago, Ill. (17). Born in Castleton, Vt., Nov. 5, 1828. Died in Havana, Cuba, March 13, 1884.

Doggett, Wm. E., Chicago, Ill. (17). Born Nov. 20, 1820. Died in 1876.

Doolittle, L., Lenoxville, C. E. (11). Died in 1862.

Dorand, Fred James, Chester, Vt. (38). Born in Rockingham, Vt., Dec. 6, 1856. Died in Aiken, S C., April 17, 1893.

Dorr, Ebenezer Pearson, Buffalo, N. Y. (25). Born in Hartford, Vt. Died in Buffalo, N. Y., April 29, 1882.

Dow, John Melmoth, New York, N. Y. (31). Died in New York, Nov. 4, 1892.

Dowling, John W., New York, N. Y. (36). Born in New York, Aug. 15, 1837. Died in Goshen, N. Y., Jan. 15, 1892.

Draper, Henry, New York, N. Y. (28). Born in New York, N. Y., March 7, 1837. Died Nov. 20, 1882.

Drowne, Charles, Canaan Four Corners, N. Y. (6). Died in 1888.

Ducatel, Julius Timoleon, Baltimore, Md. (1). Born in Baltimore, Md., June 6, 1798. Died April 25, 1849.

Duffield, George, Detroit, Mich. (10). Born in Strasburg, Pa., July 4, 1794. Died in Detroit, Mich., June 26, 1869.

Dumont, A. H., Newport, R. I. (14).

Dun, Walter Angus, Cincinnati, Ohio (31). Born March 1, 1857. Died Nov. 7, 1887.

Duncan, Lucius C., New Orleans, La. (10). Born in 1801. Died Aug. 9, 1855.

Dunn, Robinson P., Providence, R. I. (14). Born in Newport, R. I., May 31, 1825. Died in Newport, Aug. 28, 1867.

Dury, Henry M., Nashville, Tenn. (33). Died April 15, 1891.

Eads, James Buchanan, New York, N. Y. (27). Born May 23, 1820. Died March 8, 1887.

Easton, Norman, Fall River, Mass. (14). Died Dec. 21, 1872.

Eaton, James H., Beloit, Wis. (17). Died Jan. 5, 1877.

Elliott, Ezekiel Brown, Washington, D. C. (10). Born July 16, 1823. Died May 24, 1888.

Elsberg, Louis, New York, N. Y. (23). Born in Iserlohn, Prussia, April 2, 1836. Died in New York, N. Y., Feb. 19, 1885.

Elwyn, Alfred Langdon, Philadelphia, Pa. (1). Born in Portsmouth, N. H., July 9, 1804. Died in Philadelphia, Pa., March 15, 1884.

Ely, Charles Arthur, Elyria, Ohio (4).

Emerson, Geo. Barrell, Boston, Mass. (1). Born in Kennebunk, Me., Sept. 12, 1797. Died March 14, 1881.

Emmons, Ebenezer, Williamstown, Mass. (1). Born in Middlefield, Mass., May 16, 1799. Died Oct. 1, 1863.

Engelmann, George, St. Louis, Mo. (1). Born in Frankfort-on-the Main, Germany, Feb. 2, 1809. Died Feb. 4, 1884.

Engstrom, A. B., Burlington, N. J. (1).

Eustis, Henry Lawrence, Cambridge, Mass. (2). Born Feb. 1, 1819. Died Jan. 11, 1885.

Evans, Asher B., Lockport, N. Y. (19). Born in Hector, N. Y., Sept. 21, 1834. Died in Lockport, Sept. 24, 1891.

Evans, Edwin, Streator, Ill. (30). Died May 5, 1889.

Everett, Edward, Boston, Mass. (2) Born in Dorchester, Mass., April 11, 1794. Died in Boston, Mass., Jan. 15, 1865.

Ewing, Thomas, Lancaster, Ohio (5). Born in Ohio Co., Va., Dec. 28, 1789. Died Oct. 26, 1871.

Farles, R. J., Wauwatosa, Wis. (21). Died May 31, 1878.

Farmer, Moses G., Eliot, Me. (9). Died in Chicago, Ill., May 25, 1893.

Farnam, J. E., Georgetown, Ky. (26).

Farquharson, Robert James, Des Moines, Iowa (24). Born July 15, 1824. Died Sept. 6, 1884.

Felton, Samuel Morse, Philadelphia, Pa. (29). Born in Newbury, Mass., July 19, 1809. Died in Philadelphia, Pa., Jan. 24, 1889.

Ferrel, William, Kansas City, Mo. (11). Died Sept. 18, 1891.

Ferris, Isaac, New York, N. Y. (6). Born in New York, Oct. 9, 1798. Died in Roselle, N. J., June 16, 1873.

Feuchtwanger, Lewis, New York, N. Y. (11). Born in Fürth, Bavaria, Jan. 11, 1805. Died in New York, N. Y., June 25, 1876.

Ficklin, Joseph, Columbia, Mo. (20). Born in Winchester, Ky., Sept. 9, 1833. Died in Columbia, Mo., Sept. 6, 1887.

Fillmore, Millard, Buffalo, N. Y. (7). Born in New York, Jan. 7, 1800. Died March 8, 1874.

Fisher, Mark, Trenton, N. J. (10).

Fitch, Alexander, Hartford, Conn. (1). Born March 25, 1799. Died Jan. 20, 1859.

Fitch, O. H., Ashtabula, Ohio (7). Born in 1803. Died Sept. 17, 1882.

Floyd, Richard S., San Francisco, Cal. (34). Died Oct. 17, 1890.

Foote, Herbert Carrington, Cleveland, Ohio (35). Born in 1852. Died in Cleveland, Aug. 24, 1888.

Forbush, E. B., Buffalo, N. Y. (15).

Force, Peter, Washington, D. C. (4). Born in New Jersey, Nov. 26, 1790. Died in Washington, D. C., Jan. 23, 1868.

Ford, A. C., Nashville, Tenn. (26).

Forshey, Caleb Goldsmith, New Orleans, La. (21). Born in Somerset Co., Pa., July 18, 1812. Died in Carrollton, La., July 25, 1881.

Foster, John Wells, Chicago, Ill. (1). Born in Brimfield, Mass., March 4, 1815. Died in Chicago, Ill., June 29, 1873.

Foucon, Felix, Madison, Wis. (18).

Fowle, Wm. Bentley, Boston, Mass. (1). Born in Boston, Mass., Oct. 17, 1795. Died Feb. 6, 1865.

Fox, Charles, Grosse Ile, Mich. (7).

Fox, Joseph G., Easton, Pa. (31). Born in Adams, N. Y., Sept. 7, 1833. Died in Easton, Pa., Dec. 27, 1889.

Frazer, John Fries, Phila., Pa. (1). Born July 8, 1812. Died Oct. 12, 1872.

Freeman, Spencer Hedden, Cleveland, Ohio (29). Born Oct. 3, 1855. Died Feb. 2, 1886.

French, John William, West Point, N. Y. (11). Born in Connecticut, about 1810. Died in West Point, N. Y., July 8, 1871.

Fristoe, E. T., Washington, D. C. (40).

Frothingham, Frederick, Milton, Mass. (11). Born in Montreal, P. Q., April 9, 1825. Died in Milton, March 19, 1891.

Fuller, H. Weld, Boston, Mass. (29). Died Aug. 14, 1889.

Garber, A. P., Columbia, Pa. (29). Died Aug. 26, 1881.

Gardiner, Frederic, Middletown, Conn. (23). Born in Gardiner, Me., Oct. 22, 1822. Died in Middletown, Conn., July 17, 1889.

Garrison, H. D., Chicago, Ill. (31). Died in Feb., 1891.

Gavit, John E., New York, N. Y. (1) Born in New York, Oct. 29, 1819. Died in Stockbridge, Mass., Aug. 25, 1874.

Gay, Martin, Boston, Mass. (1). Born in 1804. Died Jan. 12, 1850.

Genth, Friedrich Augustus, Philadelphia, Pa. (24). Born in Waechtersbach, Hesse Cassel, May 17, 1820. Died in Philadelphia, Pa., Feb. 2, 1892.

Gibbon, J. H., Charlotte, N. C. (3).

Gilbreth, Mary E., Brookline, Mass. (42). Born May 9, 1864. Died Aug. 8, 1894.

Gillespie, William Mitchell, Schenectady, N. Y. (10). Born in New York, N. Y., 1816. Died in New York, Jan. 1, 1868.

Gilmore, Robert, Baltimore Md (1).
Glazier, W. W., Key West, Fla. (29). Died Dec. 11, 1880.
Goldmark, J., New York, N. Y. (29). Died in April, 1882.
Gordon, William J., Cleveland, Ohio (29). Died Nov. 23, 1892.
Gould, Augustus Addison, Boston, Mass. (11). Born April 23, 1805. Died Sept. 15, 1866.
Gould, Benjamin Apthorp, Boston, Mass. (2). Born in Lancaster, Mass., June 15, 1787. Died Oct. 24, 1859.
Graham, James D., Washington, D. C. (1). Born in Virginia, 1799. Died in Boston, Mass., Dec. 28, 1865.
Gray, Alonzo, Brooklyn, N. Y. (13). Born in Townsend, Vt., Feb. 21, 1808. Died in Brooklyn, N. Y., March 10. 1860
Gray, Asa, Cambridge, Mass. (1). Born in Paris, N. Y., Nov. 18, 1810. Died in Cambridge, Mass. Jan. 30, 1888.
Gray, James H., Springfield, Mass. (6).
Green, Everett Wilmer, Madison, N. J. (10). Born Oct. 5, 1834. Died in 1864.
Greene, Benjamin D., Boston, Mass. (1). Died Oct. 14, 1862, aged 68.
Greene, Samuel, Woonsocket, R. I. (9). Died in 1868.
Greer, James, Dayton, Ohio (20). Died in Feb., 1874.
Griffith, Robert Eglesfield, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Feb. 13, 1798. Died June 26, 1854.
Griswold, John Augustus, Troy, N. Y. (19). Born Nov. 11, 1818. Died Oct. 31, 1872.
Guest, William E., Ogdensburg, N. Y. (6).
Guyot, Arnold, Princeton, N. J. (1). Born Sept. 5, 1809. Died Feb. 8, 1884.

Habel, Louis, Northfield, Vt. (31).
Hackley, Charles William, New York, N. Y. (4). Born in Herkimer Co., N. Y., March 9, 1809. Died in New York, N. Y., January 10, 1861.
Hadley, George, Buffalo, N. Y. (6). Born June, 1813. Died Oct. 16, 1877.
Hagen, Hermann A., Cambridge, Mass. (17). Born in Konigsberg, Prussia, May 30, 1817. Died in Cambridge, Nov. 9, 1893.
Haldeman, Samuel Stehman, Chickies, Pa. (1). Born Aug. 12, 1812. Died Sept. 10, 1880.
Hale, Enoch, Boston, Mass (1). Born in Westhampton, Mass., Jan. 29, 1790. Died in Boston, Mass., Nov. 12, 1848.
Hamilton, Jno. M., Coudersport, Pa. (33).
Hampson, Thomas, Washington, D. C. (33).
Hance, Ebenezer, Fallsington P. O., Pa. (7). Died in 1876.
Harding, Myron H., Lawrenceburg, Ind. (30). Died Sept., 1885.
Hare, Robert, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Jan. 17, 1781. Died in Philadelphia, May 15, 1858.
Harger, Oscar, New Haven, Conn. (25). Born in Oxford, Conn., Jan. 12, 1843. Died in New Haven, Conn., Nov. 6, 1887.
Harlan, Joseph G., Haverford, Pa (8).
Harlan, Richard, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Sept. 19, 1796. Died in New Orleans, La., Sept. 30, 1843.

Harris, Geo. H., Rochester, N. Y. (35). Born in West Greece, N. Y., Dec. 29, 1843. Died in Dansville, N. Y., Oct. 5, 1893.

Harris, Thaddeus William, Cambridge, Mass. (1). Born in Dorchester, Mass., Nov. 12, 1795. Died in Cambridge, Mass., Jan. 16, 1856.

Harrison, A. M., Plymouth, Mass. (29).

Harrison, Benjamin Franklin, Wallingford, Conn. (11). Born April 19, 1811. Died April 23, 1886.

Harrison, Jos., jr., Philadelphia, Pa. (12). Born in Philadelphia, Pa., Sept. 20, 1810. Died in Philadelphia, March 27, 1874.

Hart, Simeon, Farmington, Conn. (1). Born Nov. 17, 1795. Died April 20, 1853.

Hartt, Charles Frederick, Ithaca, N. Y. (18). Born in Nova Scotia, Aug. 20, 1840. Died March 18, 1878.

Hastings, Charles W., Kansas City, Mo. (38). Died in Brooklyn, N. Y., Oct. 24, 1892.

Haven, Joseph, Chicago, Ill. (17). Born in Dennis, Mass., Jan. 4, 1816. Died May 23, 1874.

Hawes, George W., Washington, D. C. (23). Born Dec. 31, 1848. Died June 22, 1882.

Hayden, Ferdinand Vandeveer, Philadelphia, Pa. (29). Born in Westfield, Mass., Sept. 7, 1829. Died Dec. 22, 1887.

Hayden, Horace H., Baltimore, Md. (1). Born in Windsor, Conn., Oct. 13, 1769. Died in Baltimore, Md., Jan. 26, 1844.

Hayes, George E., Buffalo, N. Y. (15).

Hayward, James, Boston, Mass. (1). Born in Concord, Mass., June 12, 1786. Died in Boston, Mass., July 27, 1866.

Hazen, William Babcock, Washington, D. C. (30). Born in Hartford, Vt., Sept. 27, 1830. Died Jan. 16, 1887.

Hedrick, Benjamin Sherwood, Washington, D. C. (19). Born in 1826. Died Sept. 2, 1886.

Heighway, A. E., Cincinnati, Ohio (29). Born Dec. 26, 1820. Died Jan. 24, 1888.

Hempstead, G. S. B., Portsmouth, Ohio (29). Born in 1795. Died July 9, 1883.

Hendricks, J. E., Des Moines, Iowa (29). Died June 8, 1893, aged 79.

Henry, Joseph, Washington, D. C. (1). Born in Albany, N. Y., Dec. 17, 1797. Died May 13, 1878.

Hickox, S. V. R., Chicago, Ill. (17). Died in 1872.

Hicks, William C., New York, N. Y. (34). Died in 1885.

Hilgard, Julius Erasmus, Washington, D. C. (4). Born in Zweibrücken, Bavaria, Jan. 7, 1825. Died in Washington, D. C., May 8, 1891.

Hilgard, Theodore Charles, St. Louis, Mo. (17). Born in Zweibrücken, Bavaria, Feb. 28, 1828. Died March 5, 1875.

Hill, Walter N., Chester, Pa. (29). Born Apr. 15, 1846. Died Mar. 29, 1884.

Hincks, William, Toronto, C. W. (11). Born in 1801. Died July, 1871.

Hitchcock, Edward, Amherst, Mass. (1). Born in Deerfield, Mass., May 24, 1793. Died Feb. 27, 1864.

Hoadley, John Chipman, Boston, Mass. (29). Born Dec. 10, 1818. Died Oct. 21, 1886.

Hobbs, A. C., Bridgeport, Conn. (28). Died in Nov., 1891.

Hockley, Thomas, Philadelphia, Pa (31). Died March 12, 1892.

Hodgson, William Ballantyne, Savannah, Ga. (10). Born in Edinburgh, Scotland, in 1815.

Hogsett, John J., Danville, Ky. (39). Died Jan. 18, 1891.

Holbrook, John Edwards, Charleston, S. C. (1). Born in Beaufort, S. C., Dec. 30, 1796. Died in Norfolk, Mass. Sept. 8, 1871.

Holman, Mrs. S. W., Boston, Mass. (29). Died May 5, 1885.

Holmes, Edward J., Boston, Mass. (29). Died in July, 1884.

Holmes, Oliver Wendell, Boston, Mass. (29). Born in Cambridge, Mass., Aug. 29, 1809. Died in Boston, Oct. 7, 1894.

Holmes, Henry A., Albany, N. Y. (11). Born in Boston, Mass., March 10, 1812. Died in Albany, N. Y., Nov. 3, 1887.

Hopkins, Albert, Williamstown, Mass. (19). Born July 14, 1807. Died May 25, 1872.

Hopkins, James G., Ogdensburg, N. Y. (10). Died in 1860.

Hopkins, T. O., Williamsville, N. Y. (10). Died in 1866.

Hopkins, Wm., Lima, N. Y. (5). Died in March, 1867.

Hoppock, Albert Eugene, Hastings-on-Hudson, N. Y. (29).

Horsford, Eben Norton Cambridge, Mass. (1). Born in Moscow, N. Y., July 27, 1818. Died in Cambridge, Mass., Jan. 1, 1893.

Horton, C. V. R., Chaumont N. Y. (10). Died in 1862.

Horton, William, Craigville, N. Y. (1).

Hosford, Benj. F., Haverhill, Mass. (13). Died in 1864.

Hough, Franklin Benjamin, Lowville, N. Y. (4). Born in Martinsburgh, N. Y., July 20, 1822. Died June 11, 1885.

Houghton, Douglas, Detroit, Mich. (1). Born in Troy, N. Y., Sept. 21, 1809. Died Oct. 13, 1845.

Hovey, Edmund O., Crawfordsville, Ind. (20). Born July 15, 1801. Died March 10, 1877.

Howland, Edward Perry, Washington, D. C. (29). Born in Ledyard, N. Y., July 20, 1825. Died in Harrisburg, Pa., Sept. 12, 1888.

Howland, Theodore, Buffalo, N. Y. (15).

Hoy, Philo Romayne, Racine, Wis. (17). Born in Richland, Ohio, Nov. 3, 1816. Died in Racine, Wis., Dec. 8, 1892.

Hubbert, James, Richmond. Province of Quebec (16). Died in 1868.

Hunt, Edward Bissell, Washington, D. C. (2). Born in Livingston Co., N. Y., June 15, 1822. Died in Brooklyn, N. Y., Oct. 2, 1863.

Hunt, Freeman, New York, N. Y. (11). Born in Quincy, Mass., March 21, 1804. Died in Brooklyn, N. Y., March 2, 1858.

Hunt, Thomas Sterry, New York. N. Y. (1). Born in Norwich, Conn., Sept. 5, 1826. Died in New York, N. Y., Feb. 12, 1892.

Husted, Nathaniel C., Tarrytown-on-Hudson, N. Y. (36). Died Nov. 19, 1891.

Hyatt, Theodore, Chester, Pa. (30).

Ives, Moses B., Providence, R. I. (9). Died in 1857.
Ives, Thomas P., Providence, R. I. (10).

Jackson, Charles Thomas, Boston, Mass. (1). Born in Plymouth, Mass., June 21, 1805. Died Aug. 28 1880.
Jackson, Josiah, State College, Pa. (35). Died Oct. 10, 1893.
James, Thomas Potts, Cambridge, Mass. (22). Born Sept. 1, 1803. Died Feb 22, 1882.
Jeffries, John Amory, Boston, Mass. (38). Born in Milton, Mass., Sept. 2, 1859. Died in Boston, Mass., March 26, 1892.
Jenks, John Whipple Potter, Middleborough, Mass. (2). Born in West Boylston, Mass., May 1, 1819. Died in Providence, R I., Sept. 26, 1894.
Johnson, Hosmer A., Chicago, Ill. (17). Died in Chicago, Feb. 26, 1891.
Johnson, Walter Rogers, Washington, D. C. (1). Born in Leominster, Mass., June 21, 1794. Died April 26, 1852.
Johnson, William Schuyler, Washington, D. C. (31). Born Sept. 20, 1859. Died Oct. 6, 1883.
Jones, Catesby A. R., Washington, D. C. (8).
Jones, Henry A., Portland, Me. (29). Died Sept. 3, 1883.
Jones, James H., Boston, Mass. (28).
Jones, William S., Cleveland, Ohio (37).
Joy, Charles Arad, Stockbridge Mass. (8). Born in Ludlowville, N. Y., Oct. 8, 1823. Died in Stockbridge, Mass., May 29, 1891.

Kedzie, W. K., Oberlin, Ohio (25). Born in Kalamazoo, Mich., July 5, 1851. Died in Lansing, Mich., Apr. 10, 1880.
Keely, George W., Waterville, Me. (1). Died in 1878.
Keep, N. C., Boston, Mass. (13). Died in March, 1875.
Kellogg, James H., Rochester, N. Y. (29). Died Dec. 6, 1891.
Kendall, H. D., Grand Rapids, Mich. (35). Died in Guarymas, Mexico, Jan. 28, 1891.
Kennicott, Robert, West Northfield, Ill. (12). Born Nov. 13, 1835. Died in 1866.
Kerr, Washington Caruthers, Raleigh, N. C. (10). Born May 24, 1827. Died Aug. 9, 1885.
Kidder, Henry Purkitt, Boston, Mass. (29). Born Jan. 8, 1823. Died Jan 28, 1886.
King, Mary B. Allen, Rochester, N. Y. (15). Born in Woodstock, Vt., Jan. 26, 1799. Died in Rochester, April 3, 1893.
King, Mitchell Charleston, S. C. (3). Born in Scotland, June 8, 1783. Died Nov. 12. 1862.
Kirkpatrick, James A., Philadelphia, Pa. (7). Died June 3, 1886.
Kite, Thomas, Cincinnati, Ohio (5). Died Feb. 6, 1884.
Klippart, John H., Columbus, Ohio (17). Died October, 1878.
Knickerbocker, Charles, Chicago, Ill. (17). Died in 1873.
Knight, J. B., Philadelphia, Pa. (21). Died March 10, 1879.

Lacey, O. M., Crawfordsville, Ind (39). Died Jan. 9, 1891.

Lacklan R., Cincinnati, Ohio (11).

Lamb, Mrs. Martha J., New York, N. Y. (29). Died in Jan., 1893, aged 64.

Lapham, Increase Allen, Milwaukee, Wis. (3). Born in Palmyra, N. Y., March 7, 1811. Died in Oconomowoc, Wis., Sept. 14, 1875.

Larkin, Ethan Pendleton, Alfred Centre, N. Y. (33). Born Sept. 20, 1829. Died Aug. 23, 1887.

LaRoche, René, Philadelphia, Pa. (12). Born in Philadelphia, Pa., 1795. Died in Philadelphia, Dec , 1872.

Lasel, Edward, Williamstown, Mass. (1). Born Jan. 21, 1809. Died Jan. 31, 1852.

Lawford, Frederick, Montreal, Canada (11). Died in 1866.

Lawrence, Edward, Charlestown, Mass. (18). Born June, 1810. Died Oct 17, 1885.

Lea, Isaac, Philadelphia, Pa. (1). Born in Wilmington, Del., March 4, 1792. Died Dec. 8, 1886.

LeConte, John Lawrence, Philadelphia, Pa. (1). Born in New York, May 13, 1825. Died Nov. 15, 1883.

Lederer, Baron von, Washington, D. C. (1).

Lee, William, Washington, D. C. (29). Died March 2, 1893.

Leidy, Joseph, Philadelphia, Pa. (7). Born in Philadelphia, Sept. 9, 1823. Died in Philadelphia, April 30, 1891.

Leonard, Rensselaer, Mauch Chunk, Pa. (33). Born in Hancock, N. Y., April 12, 1821. Died in Mauch Chunk, Pa., Oct. 26, 1888.

Lewis, Elias, jr., Brooklyn, N. Y. (23). Died Feb. 3, 1894.

Lewis, Henry Carvill, Philadelphia, Pa. (26). Born in Philadelphia, Pa., Nov. 16, 1853. Died in Manchester, England, July 21, 1888.

Libbey, Joseph, Georgetown, D. C. (31). Died July 20, 1886.

Lieber, Oscar Montgomery, Columbia, S. C. (8). Born Sept 8, 1830. Died June 27, 1862.

Lilly, William, Mauch Chunk, Pa. (28). Born in Penn Yan, N. Y., June 3, 1821. Died in Mauch Chunk, Pa., Dec. 1, 1893.

Lincklaen, Ledyard, Cazenovia, N. Y. (1). Born in Cazenovia, N. Y., Oct. 17, 1820. Died April 25, 1864.

Linsley, James Harvey, Stafford, Conn. (1). Born in Northford, Conn., May 5, 1787. Died in Stratford, Conn., Dec. 26, 1843.

Lockwood, Moses B., Providence, R I. (9). Died in 1872.

Lockwood, Samuel, Freehold, N. J. (18). Born in Mansfield, England, Jan. 20, 1819. Died Jan. 9, 1894, aged 75.

Logan, William Edmond, Montreal, Canada (1). Born in Montreal, Canada, April 23, 1798. Died in Wales, June 22, 1875.

Loiseau, Emile F., Brussels, Belgium (33). Died April 30, 1886.

Loomis, Elias, New Haven, Conn. (1). Born in Willington, Conn., Aug. 7, 1811. Died in New Haven, Conn., Aug. 15, 1889.

Loosey, Charles F., New York, N. Y. (12).

Lothrop, Joshua R., Buffalo, N. Y. (15).

Lovering, Joseph, Cambridge, Mass. (2). Born in Charlestown, Mass., Dec. 25, 1813. Died in Cambridge, Mass., Jan. 18, 1892.

Lowrie, J. R., Warriorsmark, Pa. (29). Died Dec. 10, 1885.
Lucas, Mrs. John, Philadelphia, Pa. (33). Died May 8, 1893.
Lull, Edward Phelps, Washington, D. C. (28). Born Feb. 20, 1836. Died March 5, 1887.
Lyford, Moses, Springfield, Mass. (22). Born in Mt. Vernon, Me., Jan. 31, 1816. Died in Portland, Me., Aug. 4, 1887.
Lyman, Chester Smith, New Haven, Conn. (4). Born in Manchester, Conn., Jan. 13, 1814. Died in New Haven, Conn, in 1889.
Lyon, Sidney S, Jeffersonville, Ind. (20). Born Aug. 4, 1808. Died June 24, 1872.

M'Conihe, Isaac, Troy, N Y (5).
McCorkle, Spencer C., Washington, D. C. (33).
McCutchen, A R., Atlanta, Ga. (25). Died Nov. 21, 1887.
McElrath, Thomas, New York, N. Y. (36). Born in Williamsport, Pa., May 1, 1807. Died in New York, N. Y., June 6, 1888.
McFadden, Thomas, Westerville, Ohio (30). Born Nov. 9, 1825. Died Nov. 9, 1883.
McFarland, Walter, New York, N. Y. (36). Died July 22, 1888.
MacGregor, Donald. Houston, Texas (33). Died in Oct., 1887.
McLachlan, J. S., Montreal, Can. (31).
McMahon, Mathew, Albany, N. Y. (11).
McNiel, John A., Binghamton, N. Y. (35). Died in Binghamton, Dec. 20, 1891, aged 75.
Maack G. A., Cambridge, Mass. (18). Died in Aug., 1873.
Macfarlane, James, Towanda, Pa. (29). Died in 1885.
Mackintosh, James B., New York, N. Y. (27). Died in 1891.
Maffet, Wm. Ross, Wilkes Barre, Pa. (33). Died in June, 1890.
Mahan, Dennis Hart, West Point, N. Y. (9). Born in New York, N. Y., April 2, 1802. Died in New York, Sept. 16, 1871.
Mallory, Maitland L., Rochester, N. Y. (39). Died April 28, 1894.
Marler, George L., Montreal, Can. (31).
Marsh, Dexter, Greenfield, Mass. (1). Born in Montague, Mass., Aug. 22, 1806. Died in Greenfield, Mass., April 2, 1853.
Marsh, James E., Roxbury, Mass. (10).
Martin, Benjamin Nichols, New York, N. Y. (23). Born in Mount Holly, N. J., Oct. 20, 1816. Died in New York, N. Y., Dec. 26, 1883.
Martindale, Isaac C., Camden, N. J. (26). Died Jan. 3, 1893.
Mather, William Williams, Columbus, Ohio (1). Born in Brooklyn, Conn., May 24, 1804. Died in Columbus, Ohio, Feb. 27, 1859.
Maude, John B., St. Louis, Mo. (27). Died in April, 1879.
Maupin, S., Charlottesville, Va. (10).
May, Abigail Williams, Boston, Mass. (29). Born in Boston, April 21 1829. Died in Boston, Nov. 30, 1888.
Meade, George Gordon, Philadelphia, Pa. (15). Born Dec. 30, 1815. Died Nov 6, 1872.
Meek, Fielding Bradford, Washington, D. C. (6). Born Dec. 10, 1817. Died Dec. 21, 1876.

Meigs, James Aitken, Philadelphia, Pa. (12). Born July 30, 1829. Died Nov. 9, 1879.

Metcalf, Caleb B., Worcester, Mass (20). Died July 31. 1891.

Mills, Andrew G., Galveston, Texas (33). Died Feb 2, 1894

Minifie. Wm.. Baltimore. Md. (12). Born Aug. 14, 1805. Died Oct. 24, 1880.

Mitchel, Ormsby MacKnight, Cincinnati Ohio (3). Born in Union Co., Ky . July 28, 1810. Died in Beaufort, S. C., Oct. 30. 1862.

Mitchell, Miss Maria, Lynn. Mass. (4). Born in Nantucket, Mass., Aug. 1, 1818. Died in Lynn, 1889.

Mitchell, William Poughkeepsie, N. Y. (2). Born in Nantucket, Mass., Dec. 20, 1791. Died in Poughkeepsie, N. Y., April 19, 1868.

Mitchell. Wm. H . Florence Ala. (17).

Mitivier, M. M., Holyoke, Mass. (40). Died in July, 1892.

Monroe, Nathan. Bradford. Mass. (6). Born in Minot, Me., May 16, 1804. Died in Bradford, Mass., July 8, 1866.

Monroe, William, Concord, Mass. (18). Died April 27, 1877.

Moore, E. C., New York, N. Y. (30).

Morgan, Lewis Henry, Rochester, N. Y. (10). Born near Aurora, N. Y., Nov. 21, 1818. Died Dec. 17, 1881.

Morgan. Mrs. Mary E., Rochester, N. Y. (31). Died in 1884.

Morison, N. H., Baltimore, Md. (17). Born in 1815. Died Nov. 14, 1890.

Morong, Thomas, New York, N. Y. (35).

Morris, John B., Nashville, Tenn. (26).

Morris, Wistar, Philadelphia. Pa. (33). Died March 28, 1891.

Morton, Samuel George, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Jan. 26, 1799. Died in Philadelphia, May 15, 1851.

Mott, Alexander B., New York, N. Y. (36). Died Aug. 12, 1889.

Mudge, Benjamin Franklin, Manhattan, Kansas (25). Born in Orrington, Me,. Aug. 11, 1817. Died Nov. 21, 1879.

Muir, William, Montreal, Can. (31). Died July, 1885.

Mussey, William Heberdom, Cincinnati, Ohio (30). Born Sept. 30, 1818. Died Aug. 1, 1862.

Nagel, Herman, St. Louis, Mo. (30). Born in Tritzwalk, Germany, May 28, 1820. Died in St. Louis, Mo., Feb. 18, 1889.

Nettleton, Charles, New York, N. Y. (30). Born in Washington, Conn., Oct. 2, 1819. Died in New York, N. Y., May 5, 1892.

Newland, John, Saratoga Springs, N. Y. (28). Died Jan. 18, 1880.

Newton, E. H., Cambridge, N. Y. (1).

Newton, John, Pensacola, Fla. (7). Born near Pittsburgh, Pa., April 22, 1814. Died in Pensacola, Nov. 25, 1893.

Nichols, Charles A., Providence, R. I. (17). Born Jan. 4, 1826. Died Oct. 20. 1877.

Nichols, William Ripley, Boston, Mass. (18). Born April 30, 1847. Died July 14, 1886.

Nicholson, Thomas, New Orleans, La. (21).

Nicollet, Jean Nicholas, Washington, D. C. (1). Born in Savoy, France, July 24, 1786. Died in Washington, D. C., Sept. 11, 1843.

Northrop. John I., New York, N. Y. (36). Died June 26, 1891.
Norton, John Pitkin, New Haven, Conn. (1). Born July 19, 1822. Died Sept. 5, 1852.
Norton, Lewis Mills, Boston, Mass. (29). Born in Athol, Mass., Dec. 26, 1855. Died in Auburndale, Mass., April 26, 1893.
Norton, William Augustus. New Haven, Conn. (6). Born in East Bloomfield, N. Y., Oct. 25, 1810. Died Sept. 21, 1883.
Noyes, James Oscar, New Orleans, La. (21). Born in Niles, N. Y., June 14, 1829. Died in New Orleans, La., Sept. 11, 1872.
Nutt, Cyrus, Bloomington, Ind. (20). Born in Trumbull Co., Ohio, Sept. 4, 1814. Died in Bloomington, Aug. 23, 1875.

Oakes, Wm., Ipswich, Mass. (1). Born July 1, 1799. Died July 31, 1848.
Ogden, Robert W., New Orleans, La. (21). Died March 24, 1878.
Ogden, William Butler, High Bridge, N. Y. (17). Born in New York, N. Y., 1805. Died in New York, Aug. 3, 1877.
Oliver, Miss Mary E., Ithaca, N. Y. (20).
Olmsted, Alexander Fisher, New Haven, Conn. (4). Born Dec. 20, 1822. Died May 5, 1853.
Olmsted, Denison, New Haven, Conn. (1). Born in East Hartford, Conn., June 18, 1791. Died in New Haven, Conn., May 13, 1859.
Olmsted, Denison, jr., New Haven, Conn. (1). Born Feb. 16, 1824. Died Aug. 15, 1846.
Orton, James, Poughkeepsie, N. Y. (18). Born in Seneca Falls, N. Y., April 21. 1830. Died in Peru, S. A., Sept. 24, 1877.
Osbun, Isaac J.. Salem, Mass. (29).
Otis, George Alexander, Washington, D. C. (10). Born in Boston, Mass., Nov. 12, 1830. Died Feb. 29, 1881.
Owen, Richard, New Harmony, Ind. (20). Born in Scotland, Jan. 6, 1810. Died in New Harmony, March 24, 1890.

Packer, Harry E., Mauch Chunk, Pa. (30). Died Feb. 1, 1884.
Painter, Jacob, Lima, Pa. (23). Died in 1876.
Painter, Minshall, Lima Pa. (7).
Parker, Wilbur F., West Meriden, Conn. (23). Died in 1876.
Parkman, Samuel, Boston, Mass (1). Born in 1816. Died Dec. 15, 1854.
Parry, Charles C., Davenport, Iowa (6). Born in Admington. Worcestershire, Eng., Aug. 28. 1823. Died in Davenport, Iowa, Feb. 20, 1890.
Parsons, Henry Betts, New York, N. Y. (30). Born Nov. 20, 1855. Died Aug. 21, 1885.
Payn. Charles H., Saratoga Springs, N. Y. (28). Born May 16, 1814. Died Dec. 20, 1881.
Pearson, H. G., New York, N. Y. (36).
Pease, F. S , Buffalo, N. Y. (35). Died Nov. 6. 1890.
Pease, Rufus D., Philadelphia, Pa. (33). Died in 1890.
Pedrick, Mrs. William R., Lawrence, Mass. (33). Born Feb. 7, 1832. Died in Lawrence, Jan. 21, 1894.

Peirce, Benjamin Osgood, Beverly, Mass. (18). Born in Beverly, Sept. 26, 1812. Died in Beverly, Nov. 12, 1883.

Peirce, Benjamin, Cambridge, Mass. (1). Born in Salem, Mass., April 4, 1809. Died in Cambridge, Mass., Oct. 6, 1880.

Perch, Bernard, Frankford, Pa. (35). Born in 1850. Died in 1887.

Perkins, George Roberts. Utica, N. Y. (1). Born in Otsego Co., N. Y., May 3, 1812. Died in New Hartford, N. Y., Aug. 22, 1876.

Perkins, Henry C., Newburyport, Mass. (18). Born Nov. 13, 1804. Died Feb. 2, 1873.

Perry, John B., Cambridge, Mass. (16). Born in 1820. Died Oct 3, 1872.

Perry, Matthew Calbraith, New York, N. Y. (10). Born in South Kingston, R. I., 1795. Died in New York, March 4, 1858.

Phelps, Mrs. Almira Hart Lincoln, Baltimore, Md. (13). Born in Berlin, Conn., July 15, 1793. Died in Berlin, July 15, 1884.

Philbrick, Edw S., Brookline, Mass. (29). Born in Boston, Mass., Nov. 20, 1827. Died in Brookline, Mass., Feb. 13, 1889.

Phillips, John C., Boston, Mass. (29). Born in 1839. Died Mar. 1, 1885.

Piggot, A. Snowden, Baltimore, Md. (10).

Pim, Bedford Clapperton Trevelyan, London, Eng. (33). Born in England, June 12, 1826. Died Oct., 1886.

Platt, W. G., Philadelphia, Pa. (32). Died Nov., 1885.

Plumb, Ovid, Salisbury, Conn. (9).

Pope, Charles Alexander, St. Louis, Mo. (12). Born in Huntsville, Ala., March 15, 1818. Died in Paris, Mo., July 6, 1870.

Porter, John Addison, New Haven, Conn. (14). Born in Catskill, N. Y., March 15, 1822. Died in New Haven, Conn., Aug. 25, 1866.

Potter, Stephen H., Hamilton, Ohio (30). Born Nov. 10, 1812. Died Dec. 9, 1883.

Pourtalès, Louis François de, Cambridge, Mass. (1). Born March 4, 1824. Died July 19, 1880.

Pruyn, John Van Schaick Lansing, Albany, N. Y. (1). Born in Albany, N. Y., June 22, 1811. Died in Clifton Springs, N. Y., Nov. 21, 1877.

Pugh, Evan, Centre Co., Pa. (14). Born Feb. 29, 1828. Died April 29, 1864.

Pulsifer, Sidney, Philadelphia, Pa. (21). Died March 24, 1884.

Putnam, Mrs Frederic Ward, Cambridge, Mass. (19). Born in Charlestown, Mass., Dec. 29, 1838. Died in Cambridge, Mass., March 10, 1879.

Putnam, J. Duncan, Davenport, Iowa (27). Born Oct. 18, 1855. Died Dec. 10, 1881.

Quincy, Edmund, Boston, Mass. (11). Died Jan. 6, 1894.

Reid. Ezra, Terre Haute. Ind. (20). Died in 1877.

Redfield, William C., New York, N. Y. (1). Born near Middletown, Conn., March 26, 1789. Died Feb. 12, 1857.

Resor, Jacob, Cincinnati, Ohio (8). Died in 1871.

Richardson, Tobias G., New Orleans, La. (30). Died in New Orleans, May 26, 1892. Aged 65 years.

Robb, James, Fredericton, N. B. (4).

Robinson, Coleman T., Buffalo, N. Y. (15). Born in Putnam Co., N. Y., in 1838. Died near Brewster's Station, N. Y., May 1, 1872.

Rochester, Thomas Fortescue, Buffalo, N. Y. (35). Born Oct. 8, 1823. Died May 24, 1887.

Rockwell, John Arnold, Norwich, Conn. (10). Born in Norwich, Conn., August 27, 1803. Died in Washington, D. C., February 10, 1861.

Röeder, F. A., Cincinnati, Ohio (30).

Rogers, Henry Darwin, Glasgow, Scotland (1). Born in Philadelphia, Pa., Aug. 1, 1808. Died in Glasgow, Scotland, May 29, 1866.

Rogers, James Blythe, Philadelphia, Pa. (1). Born in Philadelphia, Pa., Feb. 11, 1802. Died in Philadelphia, June 15, 1852.

Rogers, Robert Empie, Philadelphia, Pa. (18). Born in Baltimore, Md., March 29, 1813. Died Sept. 6, 1884.

Rogers, William Barton, Boston, Mass. (1). Born in Philadelphia, Pa., Dec. 7, 1804. Died in Boston, May 30, 1882.

Root, Elihu, Amherst, Mass (25). Born Sept. 14, 1845.

Rutherford, Lewis M., New York, N. Y. (13). Born in Morrisania, N. Y., Nov. 25, 1816. Died in Tranquility, N. J., May 30, 1892.

Sager, Abram, Ann Arbor, Mich. (6). Born in Bethlehem, N. Y., Dec. 22, 1811. Died in Ann Arbor, Mich., August 6, 1877.

Sanders, Benjamin D., Wellsburg, W. Va. (19).

Sawyers, Mrs. Alice M. S., Fort Worth, Texas (34). Died April 25, 1893.

Scammon, Jonathan Young, Chicago, Ill. (17). Born in Whitefield, Me., in 1812. Died in Chicago, Ill., March 17, 1890.

Schæffer, George C., Washington, D. C. (1). Died in 1873.

Schimpff, Robert D., Scranton, Pa. (36).

Schley, William, New York, N. Y. (28). Died in 1882.

Schram, Nicholas Hallock, Newburgh, N. Y. (33). Died in Newburgh, N. Y., aged 54 years, 1 month and 2 days.

Schrenk, Joseph, Hoboken, N. J. (36).

Scott, Joseph, Dunham, C. E. (11). Died in 1865.

Seaman, Ezra Champion, Ann Arbor, Mich. (20). Born Oct. 14, 1805. Died July 15, 1880.

Senecal, L. A., Montreal, Can. (31).

Senter, Harvey S., Aledo, Ill. (20). Died in 1875.

Seward, William Henry, Auburn, N. Y. (1). Born in Florida, N. Y., May 16, 1801. Died in Auburn, N. Y., Oct. 10, 1872.

Seymour, William P., Troy, N. Y. (19). Died April 7, 1893.

Sheafer, Peter Wenrich, Pottsville, Pa. (4). Born in Halifax, Pa., March 31, 1819. Died in Brown's Mills in the Pines, N. J., March 26, 1891.

Sheppard, William, Drummondville, Province of Quebec, Can. (11). Born in 1783. Died in 1867.

Sherwin, Thomas, Dedham, Mass. (11). Born in Westmoreland, N. H., March 26, 1799. Died in Dedham, Mass., July 23, 1869.

Sill, Elisha N., Cuyahoga Falls, Ohio (6). Born in 1801. Died April 26, 1888.

Silliman, Benjamin. New Haven, Conn. (1). Born in North Stratford, Conn , August 8, 1779. Died in New Haven, Conn., Nov. 22, 1864.

Silliman, Benjamin. New Haven. Conn. (1). Born in New Haven, Conn., Dec. 4, 1816. Died Jan. 14, 1885.

Simpson, Edward, Washington, D. C. (28). Born in New York, N. Y., March 3. 1824. Died in Washington, D. C., Dec. 1, 1888.

Skinner, George, Kalida, Ohio (33).

Skinner, John B., Buffalo, N. Y. (15). Died in 1871.

Slack, J. H., Philadelphia, Pa. (12).

Smith, Charles A., St. Louis, Mo. (27). Died in 1884.

Smith. David P., Springfield, Mass. (29). Born Oct. 1, 1830. Died Dec. 26, 1880.

Smith. Mrs Erminnie Adelle, Jersey City, N. J. (25). Born April 26, 1836. Died June 9, 1886.

Smith, John Lawrence, Louisville, Ky. (1). Born near Charleston, S. C., Dec. 17, 1818. Died Oct. 12. 1883.

Smith, J. V., Cincinnati, Ohio (5).

Smith, James Young, Providence, R. I. (9). Born in Groton, Conn., Sept, 15, 1809. Died March 26. 1876.

Smith, Lyndon Arnold, Newark, N. J. (9). Born in Haverhill, N. H.. November 11, 1795. Died in Newark, N. J., December 15, 1865.

Smucker, Isaac, Newark, Ohio (29).

Snell, Ebenezer Strong, Amherst, Mass. (2). Born in North Brookfield, Mass., October 7, 1801. Died in Amherst. Mass.. Sept., 1877.

Sparks. Jared, Cambridge, Mass. (2). Born in Willington, Conn., May 10, 1819. Died in Cambridge, Mass., March 14, 1866.

Spinzig. Charles, St. Louis, Mo. (27). Died Jan. 22, 1882.

Squier. Ephraim George, New York, N. Y. (18). Born in Bethlehem, N. Y., June 17, 1821. Died in Brooklyn, N. Y., Apr. 17, 1888.

Stearns, Josiah A., Boston, Mass. (29).

Stearns, Silas, Pensacola Fla (28). Died Aug. 2, 1888.

Steele, Joel Dorman, Elmira, N. Y. (33). Born in Lima, N. Y., May 14, 1836. Died May 25. 1886.

Steiner, Lewis H., Baltimore, Md. (7). Born in Frederick City, Md., in 1827. Died in Baltimore, April, 1892.

Stevenson, James, Washington, D. C. (29). Born in Maysville, Ky., Dec. 24, 1810. Died in New York, N. Y., July 25, 1888.

Stimpson, Wm., Chicago, Ill. (12). Born Feb. 14, 1832. Died May 26, 1872.

Stone, Leander, Chicago. Ill. (32). Died April 2, 1888.

Stone, Samuel, Chicago, Ill. (17). Born Dec. 6, 1798. Died May 4, 1876.

St. John, Joseph S., Albany, N. Y. (28). Died Nov. 23, 1882.

Straight, H. H., Chicago, Ill. (25). Died Nov. 17, 1886.

Sturges, George, Chicago, Ill. (37). Born at Putnam, Ohio, May 13, 1838. Died at Lake Geneva, Wis., Aug. 12, 1890.

Sullivan, Algernon Sidney, New York, N. Y. (36). Born April 5, 1826. Died Dec. 4, 1887.

Sullivant, William Starling, Columbus, Ohio (7). Born near Columbus, O., Jan. 15, 1803. Died in Columbus, O., Apr. 30, 1873.

Sutton, George, Aurora, Ind. (20). Died June 13, 1886.

Swain, James, Fort Dodge, Iowa (21). Born in 1816. Died in 1877.

Tallmadge, James, New York, N. Y. (1). Born in Stamford, N. Y., Jan. 20, 1778. Died in New York, N. Y., Oct. 8, 1853.

Taylor, Arthur F., Cleveland, Ohio (29). Born Dec. 10, 1853. Died June 28, 1883.

Taylor, Richard Cowling, Philadelphia, Pa. (1). Born in England, Jan. 18, 1789. Died in Philadelphia, Pa., November 26, 1851.

Taylor, Robert N., Tollesboro, Ky. (37). Died Aug. 13, 1888.

Tenney, Sanborn, Williamstown, Mass. (17). Born in January, 1827. Died July 11, 1877.

Teschemacher, James Englehert, Boston, Mass. (1). Born in Nottingham, England, June 11, 1790. Died near Boston, Nov. 9, 1853.

Thompson, A. Remsen, New York, N. Y. (1). Died in Oct., 1879.

Thompson, Alexander, Aurora, N. Y. (1).

Thompson, Charles Oliver, Terre Haute, Ind (29). Born in East Windsor Hill, Conn., Sept. 25, 1835. Died in Terre Haute, Ind., March 17, 1885.

Thompson, Harvey M., Oakland, Cal. (17).

Thompson, Zadock, Burlington, Vt. (1). Born in Bridgewater, Vt., May 23, 1796. Died in Burlington, Vt., Jan. 19, 1856.

Thomson, Henry R., Crawfordsville, Ind. (30). Died in 1884.

Thurber, Isaac, Providence, R. I. (9).

Tileman, John Nicholas, Sandy, Utah (33). Born in Horhun, Denmark, March 28, 1845. Died in Salt Lake City, Utah, Sept. 4, 1888.

Tillman, Samuel Dyer, Jersey City, N J. (15). Born April, 1815. Died Sept. 4, 1875.

Tobin, Thomas W., Louisville, Ky. (30). Died Aug. 4, 1883.

Todd, Albert, St. Louis, Mo. (27). Born March 4, 1813. Died April 30, 1885.

Tolderoy, James B., Fredericton, N. B. (11).

Torrey, John, New York, N. Y. (1). Born in New York, N. Y., Aug. 15, 1796. Died in New York, March 10, 1873.

Torrey, Joseph, Burlington, Vt. (2). Born in Rowley, Mass., Feb. 2, 1797. Died in Burlington, Vt., Nov. 26, 1867.

Totten, Joseph Gilbert, Washington, D. C. (1). Born in New Haven, Conn., August 23, 1788. Died in Washington, D. C., April 22, 1864.

Townsend, Howard, Albany, N. Y. (10). Born Nov. 22, 1823. Died Jan. 6, 1867.

Townsend, John Kirk, Philadelphia, Pa. (1). Born Aug. 10, 1809. Died Feb. 16, 1851.

Townsend, Robert. Albany, N. Y. (9). Born 1799. Died Aug. 15, 1866.
Trembley, J. B., Oakland, Cal. (17).
Troost, Gerard, Nashville, Tenn. (1). Born in Bois-le-Duc, Holland, March 15, 1776. Died in Nashville, Tenn., Aug. 14, 1850.
Trowbridge, William Pettit, New Haven, Conn. (10). Born in Troy, Mich., in 1828. Died in New Haven, Aug. 12, 1892.
Tuomey, Michæl, Tuscaloosa, Ala. (1). Born in Ireland, September 29, 1805. Died in Tuscaloosa, Ala., March 20, 1857.
Tupper, Samuel Y., Charleston, S. C. (38). Died in 1891.
Tweedale, John B., St. Thomas, Can (35). Born in Ormskirk, Lancashire, Eng., Oct. 16, 1821. Died in St. Thomas, Can., Nov. 18, 1889.
Tyler, Edward R., New Haven, Conn. (1). Born Aug. 3, 1800. Died Sept. 28, 1848.
Tyler, Edward R., Washington, D. C. (31). Died in Washington, March 30, 1891.

Vancleve, John W., Dayton, Ohio (1).
Vanuxem, Lardner, Bristol, Pa. (1). Born in Philadelphia, Pa., July 23, 1792. Died in Bristol, Pa., June 25, 1848.
Vasey, George, Washington, D. C. (32). Died in Washington, March 4, 1893.
Vaux, William Sanson, Philadelphia, Pa. (1). Born in Philadelphia, May 19, 1811. Died in Philadelphia, May 5, 1882.

Wadsworth, James Samuel, Genesee, N. Y. (2). Born in Genesee, N. Y., October 30, 1807. Died near Chancellorsville, Va., May 8, 1864.
Wagner, Tobias, Philadelphia, Pa. (9).
Walker, J. R., Bay Saint Louis, Miss. (19). Born Aug. 7, 1830. Died June 22, 1887.
Walker, Joseph, Oxford, N. Y. (10).
Walker, Sears C., Washington, D. C. (1). Born March 28, 1805. Died January 30, 1853.
Walker, Timothy, Cincinnati, Ohio (4). Born in Wilmington, Mass., Dec. 1, 1802. Died in Cincinnati, Ohio, Jan. 15, 1856.
Walling, H. F., Cambridge, Mass. (16). Died April 8, 1888.
Walsh, Benjamin D., Rock Island, Ill. (17). Born in Frome, England, Sept. 21, 1808. Died in Rock Island, Ill., Nov. 18, 1869.
Walton, Joseph J., Philadelphia, Pa. (29). Born in Barnesville, Ohio, Nov. 1, 1855. Died in Philadelphia, Pa., Oct. 11, 1889.
Walton, Joseph R., Washington, D. C. (40). Died Sept. 23, 1892.
Wanzer, Ira, Brookfield, Conn. (18). Born in New Fairfield, Conn., April 17, 1796. Died in New Milford, Conn., March 5, 1879.
Warnecke, Carl, Montreal, Can. (31). Died May 14, 1886.
Warren, Cyrus M., Brookline, Mass. (29). Died Aug. 13, 1891.
Warren, Geo. Washington, Boston, Mass. (18). Died in 1884.
Warren, Gouverneur Kemble, Newport, R. I. (12). Born in Cold Spring, N. Y., Jan. 8, 1830. Died in Newport, R. I., Aug. 8, 1882.

Warren, John Collins, Boston, Mass. (1). Born in Boston, Mass., Aug. 1, 1778. Died in Boston, May 4, 1856.

Warren, Samuel D., Boston, Mass. (29). Born in 1817. Died May 11, 1888.

Waters, Edwin Forbes, Boston, Mass. (29). Born in Petersham, Mass. in July, 1822. Died in San Francisco, Cal., April 18, 1894.

Watertown, Charles, Wakefield, Eng. (1). Born in Wakefield, England. Died in Wakefield, May 26, 1865.

Watkins, Samuel, Nashville, Tenn. (26).

Watson, James Craig, Ann Arbor, Mich. (13). Born in Fingal, Canada, Jan. 28, 1838. Died in Madison, Wis., Nov. 23. 1880.

Watson, Sereno, Cambridge, Mass. (22). Died March 9, 1892, in the 66th year of his age.

Webster, Horace B., Albany, N. Y. (1). Born in 1812. Died Dec. 8, 1843.

Webster, J. W., Cambridge, Mass. (1). Born in 1793. Died Aug. 30, 1850.

Webster, M. H., Albany, N. Y. (1).

Weed, Monroe, Wyoming, N. Y. (6). Died in 1867.

Welch, Mrs. G. O., Lynn, Mass. (21). Died in June, 1882.

Welsh, John, Philadelphia, Pa. (33). Died May, 1886.

Weyman, George W., Pittsburgh, Pa. (6). Born April, 1832. Died July 16, 1864.

Wheatland, Henry, Salem, Mass. (1). Born in Salem, Jan. 11, 1812. Died in Salem, Feb. 27, 1893.

Wheatland, Richard H., Salem, Mass. (13). Born July 6, 1830. Died Dec. 21, 1863.

Wheatley, Charles M., Phœnixville, Pa. (1). Died May 6, 1882.

Wheeler, Arthur W., Baltimore, Md. (29). Born in March, 1859. Died Jan. 6, 1881.

Wheildon, Alice W., Concord, Mass. (31). Died June 16, 1893.

Wheildon, William W., Concord, Mass. (13). Born in 1805. Died in Concord, Mass., Jan. 7, 1892.

Whitall, Henry, Camden, N. J. (33).

White, Samuel S., Philadelphia, Pa. (23). Died Dec. 30, 1879.

Whiting, Lewis E., Saratoga Springs, N. Y. (28). Born March 7, 1815. Died Aug. 2, 1882.

Whitman, Edmund B., Cambridge, Mass. (29). Died Sept. 2, 1883.

Whitman, Wm. E., Philadelphia, Pa. (23). Died in 1875.

Whitney, Asa, Philadelphia, Pa. (1). Born Dec. 1, 1791. Died June 4, 1874.

Whittlesey, Charles, Cleveland, Ohio (1). Born in Southington, Conn., Oct. 5, 1808. Died Oct. 18, 1886.

Whittlesey, Charles C., St. Louis, Mo. (11). Died in 1872.

Wight, Orlando W., Detroit, Mich. (34).

Wilber, G. M., Pine Plains, N. Y. (19).

Wilder, Graham, Louisville, Ky. (30). Born July 1, 1843. Died Jan. 16, 1885.

Willard, Emma C. Hart, Troy, N. Y. (15). Born in Berlin, Conn., Feb. 23, 1787. Died in Troy, N. Y., April 15, 1870.

Williams, Frank, Buffalo, N. Y. (25). Died Aug. 13, 1884.

Williams, George Huntington, Baltimore, Md. (33). Died in Utica, N. Y. in July, 1894.

Williams, J. Francis, Salem, N. Y. (31). Died in 1891.

Williams, P. O., Watertown, N. Y. (24).

Williamson, Robert S., San Francisco, Cal. (12). Born in New York about 1825.

Wilson, C. H., Belize, British Honduras (30).

Wilson, Daniel, Toronto, Can. (25). Born in Edinburgh, Scotland. Died in Toronto, Aug., 1892.

Wilson, Mrs. Mary V. C., Mobile, Ala. (37). Born in Morengo County, Ala., Jan. 29, 1840. Died near Tullahoma, Tenn., June 24, 1889.

Wilson, W. C., Carlisle, Pa. (12).

Winchell, Alexander, Ann Arbor, Mich. (3). Born in North East, N. Y., Dec. 31, 1824. Died in Ann Arbor, Mich., Feb. 19, 1891.

Winlock, Joseph, Cambridge, Mass. (5). Born in Shelbyville, Ky., Feb. 6, 1826. Died in Cambridge, Mass., June 11, 1875.

Woerd, Chas. Vander, Waltham, Mass. (29). Born in Leyden, Holland, Oct. 6, 1821. Died near Dagget, Cal., Dec. 29, 1888.

Wood, Robert W., Jamaica Plain, Mass. (29).

Woodbury, Levi, Portsmouth, N. H. (1). Born in Francistown, N. H., Dec. 22, 1789. Died Sept. 4, 1851.

Woodman, John Smith, Hanover, N. H. (11). Born in Durham, N. H., Sept. 6, 1819. Died in Durham, N. H., May 15, 1871.

Woodward, A. E., Jefferson City, Mo. (39). Died in Montana, Sept. 20, 1891.

Woodward, Joseph Janvier, Washington, D. C. (28). Born in Philadelphia, Pa., Oct. 30, 1833. Died near that city, Aug. 17, 1884.

Worthen, Amos Henry, Springfield, Ill. (5). Born Oct. 31, 1813. Died May 6, 1888.

Worthington, George, New York, N. Y. (36). Died Feb. 1, 1892.

Wright Elizur, Boston, Mass. (31). Born in South Canaan, Conn., Feb. 12, 1804. Died Nov. 20, 1885.

Wright, Harrison, Wilkes Barre, Pa. (29). Born July 15, 1850. Died Feb. 20, 1885.

Wright, John, Troy, N. Y. (1).

Wyman, Jeffries, Cambridge, Mass. (1). Born in Chelmsford, Mass., Aug. 11, 1814. Died in Bethlehem, N. H., Sept. 4, 1874.

Wyckoff, William Cornelius, New York, N. Y. (20). Born in New York, N. Y., May 28, 1832. Died in Brooklyn, N. Y., May 2, 1888.

Yarnall, M., Washington, D. C. (26). Born in 1817. Died Jan. 27, 1879,

Youmans, Edward Livingston, New York, N. Y. (6). Born in Coeymans, N. Y., June 3, 1821. Died Jan. 18, 1887.

Young, Ira, Hanover, N. H. (1). Born in Lebanon, N. H., May 23, 1801. Died in Hanover, N. H., Sept. 14, 1858.

Zentmayer, Joseph, Philadelphia, Pa. (29). Died, 1887.

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ADDRESS

BY

WILLIAM HARKNESS,

THE RETIRING PRESIDENT OF THE ASSOCIATION.

ON THE MAGNITUDE OF THE SOLAR SYSTEM.

NATURE may be studied in two widely different ways. On the one hand, we may employ a powerful microscope which will render visible the minutest forms and limit our field of view to an infinitesimal fraction of an inch situated within a foot of our own noses; or on the other hand, we may occupy some commanding position from which, aided perhaps by a telescope, we may ob tain a comprehensive view of an extensive region. The first method is that of the specialist, the second is that of the philosopher; but both are necessary for an adequate understanding of nature. The one has brought us knowledge wherewith to defend ourselves against bacteria and microbes which are among the most deadly enemies of mankind, and the other has made us acquainted with the great laws of matter and force, upon which rests the whole fabric of science. All nature is one, but for convenience of classification we have divided our knowledge into a number of sciences, which we usually regard as quite distinct from each other. Along certain lines, or, more properly, in certain regions, these sciences necessarily abut on each other, and just there lies the weakness of the specialist. He is like a wayfarer who always finds obstacles in crossing the boundaries between two countries, while to the traveller who gazes over them from a commanding eminence, the case is quite different. If the boundary is an ocean shore there is no mistaking it; if a broad river or a chain of mountains, it is still distinct; but if only a line of posts traced over

hill and dale, then it becomes lost in the natural features of the landscape, and the essential unity of the whole region is apparent. In that case the border land is wholly a human conception of which nature takes no cognizance, and so it is with the scientific border land to which I propose to invite your attention this evening.

To the popular mind there are no two sciences farther apart than astronomy and geology. The one treats of the structure and mineral constitution of our earth, the causes of its physical features and its history; while the other treats of the celestial bodies, their magnitudes, motions, distances, periods of revolution, eclipses, order, and of the causes of their various phenomena. And yet many, perhaps I may even say most, of the apparent motions of the heavenly bodies are merely reflections of the motions of the earth, and in studying them we are really studying it. Furthermore, precession, nutation and the phenomena of the tides depend largely upon the internal structure of the earth, and there astronomy and geology merge into each other. Nevertheless, the methods of the two sciences are widely different, most astronomical problems being discussed quantitatively by means of rigid mathematical formulæ, while in the vast majority of cases the geological ones are discussed only qualitatively, each author contenting himself with a mere statement of what he thinks. With precise data the methods of astronomy lead to very exact results, for mathematics is a mill which grinds exceeding fine; but after all, what comes out of a mill depends wholly upon what is put into it, and if the data are uncertain, as is the case in most cosmological problems, there is little to choose between the mathematics of the astronomer and the guesses of the geologist.

If we examine the addresses delivered by former presidents of this Association, and of the sister, perhaps it would be nearer the truth to say the parent, Association on the other side of the Atlantic, we shall find that they have generally dealt either with the recent advances in some broad field of science, or else with the development of some special subject. This evening I propose to adopt the latter course, and I shall invite your attention to the present condition of our knowledge respecting the magnitude of the solar system; but in so doing it will be necessary to introduce some considerations derived from laboratory experiments upon the luminiferous ether, others derived from experiments upon ponderable matter, and still others relating both to the surface phenomena

and to the internal structure of the earth, and thus we shall deal largely with the border land where astronomy, physics and geology merge into each other.

The relative distances of the various bodies which compose the solar system can be determined to a considerable degree of approximation with very crude instruments as soon as the true plan of the system becomes known, and that plan was taught by Pythagoras more than five hundred years before Christ. It must have been known to the Egyptians and Chaldeans still earlier, if Pythagoras really acquired his knowledge of astronomy from them, as is affirmed by some of the ancient writers, but on that point there is no certainty. In public, Pythagoras seemingly accepted the current belief of his time, which made the earth the center of the universe, but to his own chosen disciples he communicated the true doctrine that the sun occupies the center of the solar system, and that the earth is only one of the planets revolving around it. Like all the world's greatest sages, he seems to have taught only orally. A century elapsed before his doctrines were reduced to writing by Philolaus of Crotona, and it was still later before they were taught in public for the first time by Hicetas, o as he is sometimes called, Nicetas, of Syracuse. Then the familiar cry of impiety was raised, and the Pythagorean system was eventually suppressed by that now called the Ptolemaic, which held the field until it was overthrown by Copernicus, almost two thousand years later. Pliny tells us that Pythagoras believed the distances to the sun and moon to be respectively 252,000 and 12,600 stadia, or taking the stadium at 625 feet, 29,837 and 1,492 English miles; but there is no record of the method by which these numbers were ascertained.

After the relative distances of the various planets are known, it only remains to determine the scale of the system, for which purpose the distance between any two planets suffices. We know little about the early history of the subject, but it is clear that the primitive astronomers must have found the quantities to be measured too small for detection with their instruments, and even in modern times the problem has proved to be an extremely difficult one. Aristarchus of Samos, who flourished about 270 B. C., seems to have been the first to attack it in a scientific manner. Stated in modern language, his reasoning was that when the moon was exactly half full, the earth and sun as seen from its center must make a right angle with each other, and by measuring the

angle between the sun and moon, as seen from the earth at that instant, all the angles of the triangle joining the earth, sun and moon would become known, and thus the ratio of the distance of the sun to the distance of the moon would be determined. Although perfectly correct in theory, the difficulty of deciding visually upon the exact instant when the moon is half full is so great that it cannot be accurately done even with the most powerful telescopes. Of course Aristarchus had no telescope, and he does not explain how he effected the observation, but his conclusion was that at the instant in question the distance between the centers of the sun and moon as seen from the earth, is less than a right angle by $\frac{1}{30}$ part of the same. We should now express this by saying that the angle is 87 degrees, but Aristarchus knew nothing of trigonometry, and in order to solve his triangle he had recourse to an ingenious, but long and cumbersome geometrical process which has come down to us, and affords conclusive proof of the condition of Greek mathematics at that time. His conclusion was that the sun is nineteen times farther from the earth than the moon, and if we combine that result with the modern value of the moon's parallax, viz., 3422.38″, we obtain for the solar parallax 180″, which is more than twenty times too great.

The only other method of determining the solar parallax known to the ancients was that devised by Hipparchus about 150 B. C. It was based on measuring the rate of decrease of the diameter of the earth's shadow cone by noting the duration of lunar eclipses, and as the result deduced from it happened to be nearly the same as that found by Aristarchus, substantially his value of the parallax remained in vogue for nearly two thousand years, and the discovery of the telescope was required to reveal its erroneous character. Doubtless this persistency was due to the extreme minuteness of the true parallax, which we now know is far too small to have been visible upon the ancient instruments, and thus the supposed measures of it were really nothing but measures of their inaccuracy.

The telescope was first pointed to the heavens by Galileo in 1609, but it needed a micrometer to convert it into an accurate measuring instrument, and that did not come into being until 1639, when it was invented by William Gascoigne. After his death in 1644, his original instrument passed to Richard Townley, who attached it to a fourteen-foot telescope at his residence in Townley, Lancashire, England, where it was used by Flamsteed in observing the

diurnal parallax of Mars during its opposition in 1672. A description of Gascoigne's micrometer was published in the Philosophical Transactions in 1667, and a little before that a similar instrument had been invented by Auzout in France, but observatories were fewer then than now, and so far as I know, J. D. Cassini was the only person beside Flamsteed who attempted to determine the solar parallax from that opposition of Mars. Foreseeing the importance of the opportunity, he had Richer dispatched to Cayenne some months previously, and when the opposition came he effected two determinations of the parallax; one being by the diurnal method, from his own observations in Paris, and the other by the meridian method, from observations in France, by himself, Römer and Picard, combined with those of Richer at Cayenne. This was the transition from the ancient instruments with open sights, to telescopes armed with micrometers, and the result must have been little short of stunning to the seventeenth-century astronomers, for it caused the hoary and gigantic parallax of about 180″ to shrink incontinently to 10″, and thus expanded their conception of the solar system to something like its true dimensions. More than fifty years previously, Kepler had argued from his ideas of the celestial harmonies that the solar parallax could not exceed sixty seconds, and a little later Horrocks had shown on more scientific grounds that it was probably as small as fourteen seconds, but the final death blow to the ancient values ranging as high as two or three minutes came from these observations of Mars by Flamsteed, Cassini and Richer.

Of course the results obtained in 1672 produced a keen desire on the part of astronomers for further evidence respecting the true value of the parallax, and as Mars comes into a favorable position for such investigations only at intervals of about sixteen years, they had recourse to observations of Mercury and Venus. In 1677 Halley observed the diurnal parallax of Mercury, and also a transit of that planet across the sun's disk, at St. Helena, and in 1681, J. D. Cassini and Picard observed Venus when she was on the same parallel with the sun, but although the observations of Venus gave better results than those of Mercury, neither of them was conclusive, and we now know that such methods are inaccurate even with the powerful instruments of the present day. Nevertheless, Halley's attempt by means of the transit of Mercury ultimately bore fruit in the shape of his celebrated paper of 1716, wherein

he showed the peculiar advantages of transits of Venus for determining the solar parallax. The idea of utilizing such transits for this purpose seems to have been vaguely conceived by James Gregory, or perhaps even by Horrocks, but Halley was the first to work it out completely, and long after his death his paper was mainly instrumental in inducing the governments of Europe to undertake the observations of the transits of Venus in 1761 and 1769, from which our first accurate knowledge of the sun's distance was obtained.

Those who are not familiar with practical astronomy may wonder why the solar parallax can be got from Mars and Venus, but not from Mercury, or the sun itself. The explanation depends on two facts. First, the nearest approach of these bodies to the earth is for Mars 33,874,000 miles, for Venus 23,654,000 miles, for Mercury 47,935,000 miles, and for the sun 91,239,000 miles. Consequently, for us Mars and Venus have very much larger parallaxes than Mercury or the sun, and of course the larger the parallax the easier it is to measure. Secondly, even the largest of these parallaxes must be determined within far less than one-tenth of a second of the truth, and while that degree of accuracy is possible in measuring short arcs, it is quite unattainable in long ones. Hence one of the most essential conditions for the successful measurements of parallaxes is that we shall be able to compare the place of the near body with that of a more distant one situated in the same region of the sky. In the case of Mars that can always be done by making use of a neighboring star, but when Venus is near the earth she is also so close to the sun that stars are not available, and consequently her parallax can be satisfactorily measured only when her position can be accurately referred to that of the sun, or in other words, only during her transits across the sun's disk. But even when the two bodies to be compared are sufficiently near each other, we are still embarrassed by the fact that it is more difficult to measure the distance between the limb of a planet and a star or the limb of the sun than it is to measure the distance between two stars, and since the discovery of so many asteroids, that circumstance has led to their use for determinations of the solar parallax. Some of these bodies approach within 75,230,000 miles of the earth's orbit, and as they look precisely like stars, the increased accuracy of pointing on them fully makes up for their greater distance, as compared with Mars or Venus.

After the Copernican system of the world and the Newtonian theory of gravitation were accepted, it soon became evident that trigonometrical measurements of the solar parallax might be supplemented by determinations based on the theory of gravitation, and the first attempts in that direction were made by Machin in 1729 and T. Mayer in 1753. The measurement of the velocity of light between points on the earth's surface, first effected by Fizeau in 1849, opened up still other possibilities; and thus for determining the solar parallax we now have at our command no less than three entirely distinct classes of methods which are known respectively as the trigonometrical, the gravitational and the phototachymetrical. We have already given a summary sketch of the trigonometrical methods, as applied by the ancient astronomers to the dichotomy and shadow cone of the moon, and by the moderns, to Venus, Mars and the asteroids, and we shall next glance briefly at the gravitational and photo-tachymetrical methods.

The gravitational results which enter directly or indirectly into the solar parallax are six in number, to wit: first, the relation of the moon's mass to the tides; second, the relation of the moon's mass and parallax to the force of gravity at the earth's surface; third, the relation of the solar parallax to the masses of the earth and moon; fourth, the relation of the solar and lunar parallaxes to the moon's mass and parallactic inequality; fifth, the relation of the solar and lunar parallaxes to the moon's mass and the earth's lunar inequality; sixth, the relation of the constants of nutation and precession to the moon's parallax.

Respecting the first of these relations it is to be remarked that the tide-producing forces are the attraction of the sun and moon upon the waters of the ocean, and from the ratio of these attractions the moon's mass can readily be determined. But unfortunately the ratio of the solar tides to the lunar tides is affected both by the depth of the sea and by the character of the channels through which the water flows, and for that reason the observed ratio of these tides requires multiplication by a correcting factor in order to convert it into the ratio of the forces. The matter is further complicated by this correcting factor varying from port to port, and in order to get satisfactory results long series of observations are necessary. The labor of deriving the moon's mass in this way was formerly so great that for more than half a century La Place's determination from the tides at Brest remained unique,

but the recent application of harmonic analysis to the data supplied by self-registering tide gauges is likely to yield abundant results in the near future.

Our second gravitational relation, viz., that connecting the moon's mass and parallax with the force of gravity at the earth's surface, affords an indirect method of determining the moon's parallax with very great accuracy if the computation is carefully made, and with a fair approximation to the truth even when the data are exceedingly crude. To illustrate this, let us see what could be done with a railroad transit such as is commonly used by surveyors, a steel tape, and a fairly good watch. Neglecting small corrections due to the flattening of the earth, the centrifugal force at its surface, the eccentricity of its orbit, and the mass of the moon; the law of gravitation shows that if we multiply together the length of the seconds pendulum, the square of the radius of the earth, and the square of the length of the sidereal month, divide the product by four, and take the cube root of the quotient, the result will be the distance from the earth to the moon. To find the length of the seconds pendulum we would rate the watch by means of the railroad transit, and then making a pendulum out of a spherical leaden bullet suspended by a fine thread, we would adjust the length of the thread until the pendulum made exactly three hundred vibrations in five minutes by the watch. Then, supposing the experiment to be made here, or in New York city, we should find that the distance from the point of suspension of the thread to the center of the bullet was about $39\frac{1}{8}$ inches, and dividing that by the number of inches in a mile, viz, 63,360, we should have for the length of the seconds pendulum $\frac{1}{1620}$ of a mile. The next step would be to ascertain the radius of the earth, and the quickest way of doing so would probably be, first to determine the latitude of some point in New York city by means of the railroad transit, next to run a traverse survey along the old Post Road from New York to Albany, and finally to determine the latitude of some point in Albany. The traverse survey should surely be correct to one part in three hundred, and as the distance between the two cities is about two degrees, the difference of latitude might be determined to about the same percentage of accuracy. In that way we should find the length of two degrees of latitude to be about 138 miles, whence the earth's radius would be 3,953 miles. It would then only remain

to observe the time occupied by the moon in making a sidereal revolution around the earth, or in other words the time which she occupies in moving from any given star back to the same star again. By noting that to within one-quarter of her own diameter we would soon find that the time of a revolution is about 27.32 days, and multiplying that by the number of seconds in a day, viz., 86,400, we would have for the length of the sidereal month 2,360,000 seconds. With these data the computation would stand as follows: the radius of the earth, 3,953 miles, multiplied by the length of a sidereal month, 2,360,000 seconds, and the product squared, gives 87,060,000,000,000,000,000. Multiplying that by one-fourth of the length of the seconds pendulum, viz., $\frac{1}{6\frac{1}{8}0}$ of a mile, and extracting the cube root of the product, we would get 237,700 miles for the distance from the earth to the moon, which is only about 850 miles less than the truth, and is certainly a remarkable result considering the crudeness of the instruments by which it might be obtained. Nevertheless, when all the conditions are rigorously taken into account these data are to be regarded as determining the relation between the moon's mass and parallax rather than the parallax itself.

Our third gravitational relation, to wit, that existing between the solar parallax, the solar attractive force and the masses of the earth and moon, is analogous to the relation existing between the moon's mass and parallax and the force of gravity at the earth's surface; but it cannot be applied in exactly the same way on account of our inability to swing a pendulum on the sun. We are therefore compelled to adopt some other method of determining the sun's attractive force, and the most available is that which consists in observing the perturbative action of the earth and moon upon our nearest planetary neighbors, Venus and Mars. From this action the law of gravitation enables us to determine the ratio of the sun's mass to the combined masses of the earth and moon, and then the relation in question furnishes a means of comparing the masses so found with trigonometrical determinations of the solar parallax. Thus it appears that notwithstanding necessary differences in the methods of procedure, the analogy between the second and third gravitational relations holds not only with respect to their theoretical basis, but also in their practical application, the one being used to determine the relation between the mass of the moon and its distance from the earth, and the other to determine

the relation between the combined masses of the earth and moon and their distance from the sun.

Our fourth gravitational relation deals with the connection between the solar parallax, the lunar parallax, the moon's mass and the moon's parallactic inequality. The important quantities are here the solar parallax and the moon's parallactic inequality, and although the derivation of the complete expression for the connection between them is a little complicated, there is no difficulty in getting a general notion of the forces involved. As the moon moves around the earth she is alternately without and within the earth's orbit. When she is without, the sun's attraction on her acts with that of the earth; when she is within, the two attractions act in opposite directions. Thus in effect the centripetal force holding the moon to the earth is alternately increased and diminished, with the result of elongating the moon's orbit towards the sun and compressing it on the opposite side. As the variation of the centripetal force is not great, the change of the form of the orbit is small; nevertheless the summation of the minute alterations thereby produced in the moon's orbital velocity suffices to put her sometimes ahead, and sometimes behind her mean place to an extent which oscillates from a maximum to a minimum as the earth passes from perihelion to aphelion, and averages about 125 seconds of arc. This perturbation of the moon is known as the parallactic inequality, because it depends on the earth's distance from the sun, and can therefore be expressed in terms of the solar parallax. Conversely, the solar parallax can be deduced from the observed value of the parallactic inequality, but unfortunately there are great practical difficulties in making the requisite observations with a sufficient degree of accuracy. Notwithstanding the ever recurring talk about the advantages to be obtained by observing a small well defined crater instead of the moon's limb, astronomers have hitherto found it impracticable to use anything but the limb, and the disadvantage of doing so as compared with observing a star is still further increased by the circumstance that in general only one limb can be seen at a time, the other being shrouded in darkness. If both limbs could always be observed we should then have a uniform system of data for determining the place of the center; but under existing circumstances we are compelled to make our observations half upon one limb and half upon the other, and thus they involve all the systematic errors which may arise from

the conditions under which these limbs are observed, and all the uncertainty which attaches to irradiation, personal equation, and our defective knowledge of the moon's semi-diameter.

Our fifth gravitational relation is that which exists between the solar parallax, the lunar parallax, the moon's mass and the earth's lunar inequality. Strictly speaking the moon does not revolve around the earth's center, but both bodies revolve around the common center of gravity of the two. In consequence of that an irregularity arises in the earth's orbital velocity around the sun, the common center of gravity moving in accordance with the laws of elliptic motion, while the earth, on account of its revolution around that center, undergoes an alternate acceleration and retardation which has for its period a lunar month, and is called the lunar inequality of the earth's motion. We perceive this inequality as an oscillation superposed on the elliptic motion of the sun, and its semi-amplitude is a measure of the angle subtended at the sun by the interval between the center of the earth and the common center of gravity of the earth and moon. Just as an astronomer on the moon might use the radius of her orbit around the earth as a base for measuring her distance from the sun, so we may use this interval for the same purpose. We find its length in miles from the equatorial semi-diameter of the earth, the moon's parallax and the moon's mass, and thus we have all the data for determining the solar parallax from the inequality in question. In view of the great difficulty which has been experienced in measuring the solar parallax itself, it may be asked why we should attempt to deal with the parallactic inequality which is about twenty-six per cent smaller. The answer is, because the latter is derived from differences of the sun's right ascension which are furnished by the principal observatories in vast numbers, and should give very accurate results on account of their being made by methods which insure freedom from constant errors. Nevertheless, the sun is not so well adapted for precise observations as the stars, and Dr. Gill has recently found that heliometer measurements upon asteroids which approach very near to the earth yield values of the parallactic inequality superior to those obtained from right ascensions of the sun.

Our sixth gravitational relation is that which exists between the moon's parallax and the constants of precession and nutation. Every particle of the earth is attracted both by the sun and by the

moon, but in consequence of the polar flattening the resultant of these attractions passes a little to one side of the earth's center of gravity. Thus a couple is set up, which, by its action upon the rotating earth, causes the axis thereof to describe a surface which may be called a fluted cone, with its apex at the earth's center. A top spinning with its axis inclined describes a similar cone, except that the flutings are absent and the apex is at the point upon which the spinning occurs. For convenience of computation we resolve this action into two components, and we name that which produces the cone the luni solar precession, and that which produces the flutings the nutation. In this phenomenon the part played by the sun is comparatively small, and by eliminating it we obtain a relation between the luni-solar precession, the nutation and the moon's parallax which can be used to verify and correct the observed values of these quantities.

In the preceding paragraph we have seen that the relation between the quantities there considered depends largely upon the flattening of the earth, and thus we are led to inquire how and with what degree of accuracy that is determined. There are five methods, viz.: one geodetic, one gravitational, and three astronomical. The geodetic method depends upon measurements of the length of a degree on various parts of the earth's surface, and with the data hitherto accumulated it has proved quite unsatisfactory. The gravitational method consists in determining the length of the seconds pendulum over as great a range of latitude as possible, and deducing therefrom the ratio of the earth's polar and equatorial semi-diameters by means of Clairaut's theorem. The pendulum experiments show that the earth's crust is less dense on mountain plateaus than at the seacoast, and thus for the first time we are brought into contact with geological considerations. The first astronomical method consists in observing the moon's parallax from various points on the earth's surface, and as these parallaxes are nothing else than the angular semi-diameter of the earth at the respective points as seen from the moon, they afford a direct measure of the flattening. The second and third astronomical methods are based upon certain perturbations of the moon which depend upon the figure of the earth, and should give extremely accurate results, but unfortunately very great difficulties oppose themselves to the exact measurement of the perturbations. There is also an astronomico-geological method which cannot yet

be regarded as conclusive on account of our lack of knowledge respecting the law of density which prevails in the interior of the earth. It is based upon the fact that a certain function of the earth's moments of inertia can be determined from the observed values of the coëfficients of precession and nutation, and could also be determined from the figure and dimensions of the earth if we knew the exact distribution of matter in its interior. Our present knowledge on that subject is limited to a superficial layer not more than ten miles thick, but it is usual to assume that the deeper matter is distributed according to La Grange's law, and then by writing the function in question in a form which leaves the flattening indeterminate, and equating the expression so found to the value given by the precession and nutation, we readily obtain the flattening. As yet these six methods do not give consistent results, and so long as serious discrepancies remain between them there can be no security that we have arrived at the truth.

It should be remarked that in order to compute the function of the earth's moments of inertia which we have just been considering, we require not only the figure and dimensions of the earth and the law of distribution of density in its interior, but also its mean and surface densities. The experiments for determining the mean density have consisted in comparing the earth's attraction with the attraction either of a mountain, or of a known thickness of the earth's crust, or of a known mass of metal. In the case of mountains the comparisons have been made with plumb lines and pendulums; in the case of known layers of the earth's crust they have been made by swinging pendulums at the surface and down in mines; and in the case of known masses of metal they have been made with torsion balances, fine chemical balances and pendulums. The surface density results from a study of the materials composing the earth's crust, but notwithstanding the apparent simplicity of that process, it is doubtful if we have yet attained as accurate a result as in the case of the mean density.

Before quitting this part of our subject, it is important to point out that the luni-solar precession can not be directly observed, but must be derived from the general precession. The former of these quantities depends only upon the action of the sun and moon, while the latter is affected in addition by the action of all the planets, and to ascertain what that is we must determine their masses. The methods of doing so fall into two great classes ac-

cording as the planets dealt with have or have not satellites. The most favorable case is that in which one or more satellites are present, because the mass of the primary follows immediately from their distances and revolution times, but even then there is a difficulty in the way of obtaining very exact results. By extending the observations over sufficiently long periods the revolution times can be ascertained with any desired degree of accuracy, but all measurements of the distance of a satellite from its primary are affected by personal equation, which we can not be sure of completely eliminating, and thus a considerable margin of uncertainty is brought into the masses. In the cases of Mercury and Venus, which have no satellites, and to a certain extent in the case of the earth also, the only available way of ascertaining the masses is from the perturbations produced by the action of the various planets on each other. These perturbations are of two kinds, periodic and secular. When sufficient data have been accumulated for the exact determination of the secular perturbations, they will give the best results, but as yet it remains advantageous to employ the periodic perturbations also.

Passing now to the photo-tachymetrical methods, we have first to glance briefly at the mechanical appliances by which the tremendous velocity of light has been successfully measured. They are of the simplest possible character, and are based either upon a toothed wheel, or upon a revolving mirror.

The toothed-wheel method was first used by Fizeau in 1849. To understand its operation, imagine a gun barrel with a toothed wheel revolving at right angles to its muzzle in such a way that the barrel is alternately closed and opened as the teeth and the spaces between them pass before it. Then, with the wheel in rapid motion, at the instant when a space is opposite the muzzle let a ball be fired. It will pass out freely, and after traversing a certain distance let it strike an elastic cushion and be reflected back upon its own path. When it reaches the wheel, if it hits a space it will return into the gun barrel, but if it hits a tooth it will be stopped. Examining the matter a little more closely, we see that as the ball requires a certain time to go and return, if during that time the wheel moves through an odd multiple of the angle between a space and a tooth, the ball will be stopped, while if it moves through an even multiple of that angle the ball will return into the barrel. Now imagine the gun barrel, the ball and the

elastic cushion to be replaced respectively by a telescope, a light wave and a mirror. Then if the wheel moved at such a speed that the returning light wave struck against the tooth following the space through which it issued, to an eye looking into the telescope all would be darkness. If the wheel moved a little faster and the returning light wave passed through the space succeeding that through which it issued, the eye at the telescope would perceive a flash of light; and if the speed were continuously increased a continual succession of eclipses and illuminations would follow each other according as the returning light was stopped against a tooth or passed through a space farther and farther behind that through which it issued. Under these conditions the time occupied by the light in traversing the space from the wheel to the mirror and back again would evidently be the same as the time required by the wheel to revolve through the angle between the space through which the light issued and that through which it returned, and thus the velocity of light would become known from the distance between the telescope and the mirror together with the speed of the wheel. Of course the longer the distance traversed, and the greater the velocity of the wheel, the more accurate would be the result.

The revolving-mirror method was first used by Foucault in 1862. Conceive the toothed wheel of Fizeau's apparatus to be replaced by a mirror attached to a vertical axis, and capable of being put into rapid rotation. Then it will be possible so to arrange the apparatus that light issuing from the telescope shall strike the movable mirror and be reflected to the distant mirror, whence it will be returned to the movable mirror again and being thrown back into the telescope will appear as a star in the center of the field of view. That adjustment being made, if the mirror were caused to revolve at a speed of some hundred turns per second it would move through an appreciable angle while the light was passing from it to the distant mirror and back again, and in accordance with the laws of reflection, the star in the field of the telescope would move from the center by twice the angle through which the mirror had turned. Thus the deviation of the star from the center of the field would measure the angle through which the mirror turned during the time occupied by light in passing twice over the interval between the fixed and revolving mirrors, and from the magnitude of that angle together with the known speed of the mirror, the velocity of the light could be calculated.

In applying either of these methods the resulting velocity is that of light when traversing the earth's atmosphere, but what we want is its velocity in space which we suppose to be destitute of ponderable material, and in order to obtain that the velocity in the atmosphere must be multiplied by the refractive index of air. The corrected velocity so obtained can then be used to find the solar parallax, either from the time required by light to traverse the semi-diameter of the earth's orbit, or from the ratio of the velocity of light to the orbital velocity of the earth.

Any periodic correction which occurs in computing the place of a heavenly body, or the time of a celestial phenomenon, is called by astronomers an equation; and as the time required by light to traverse the semi-diameter of the earth's orbit first presented itself in the guise of a correction to the computed times of the eclipses of Jupiter's satellites, it has received the name of the light equation. The earth's orbit being interior to that of Jupiter, and both having the sun for their center, it is evident that the distance between the two planets must vary from the sun to the difference of the radii of their respective orbits, and the time required by light to travel from one planet to the other must vary proportionately. Consequently, if the observed times of the eclipses of Jupiter's satellites are compared with the times computed upon the assumption that the two planets are always separated by their mean distance it will be found that the eclipses occur too early when the earth is at less than its mean distance from Jupiter, and too late when it is farther off, and from large numbers of such observations the value of the light equation has been deduced.

The combination of the motion of light through our atmosphere with the orbital motion of the earth gives rise to the annual aberration, all the phases of which are computed from its maximum value, commonly called the constant of aberration. There is also a diurnal aberration due to the rotation of the earth on its axis, but that is quite small and does not concern us this evening. When aberration was discovered the corpuscular theory of light was in vogue, and it offered a charmingly simple explanation of the whole phenomenon. The hypothetical light corpuscles impinging upon the earth were thought to behave precisely like the drops in a shower of rain, and you all know that their apparent direction is affected by any motion on the part of the observer. In a calm day when the drops are falling perpendicularly, a man standing still holds his umbrella directly over his head, but as soon as he

begins to move forward he inclines his umbrella in the same direction, and the more rapidly he moves the greater must be its inclination in order to meet the descending shower. Similarly, the apparent direction of on-coming light corpuscles would be affected by the orbital motion of the earth, so that in effect it would always be the resultant arising from combining the motion of the light with a motion equal and opposite to that of the earth. But since the falsity of the corpuscular theory has been proved that explanation is no longer tenable, and as yet we have not been able to replace it with anything equally satisfactory based on the now universally accepted undulatory theory. In accordance with the latter theory we must conceive the earth as plowing its way through the ether, and the point which has hitherto baffled us is whether or not in so doing it produces any disturbance of the ether which affects the aberration. In our present ignorance on that point we can only say that the aberration constant is certainly very nearly equal to the ratio of the earth's orbital velocity to the velocity of light, but we cannot affirm that it is rigorously so.

The luminiferous ether was invented to account for the phenomena of light, and for two hundred years it was not suspected of having any other function. The emission theory postulated only the corpuscles which were supposed to constitute light itself, but the undulatory theory fills all space with an imponderable substance possessing properties even more remarkable than those of ordinary matter, and to some of the acutest intellects the magnitude of this idea has proved an almost insuperable objection against the whole theory. So late as 1862 Sir David Brewster, who had gained a world-wide reputation by his optical researches, expressed himself as staggered by the notion of filling all space with some substance merely to enable a little twinkling star to send its light to us; but not long after Clerk Maxwell removed that difficulty by a discovery coëxtensive with the undulatory theory itself. Since 1845, when Faraday first performed his celebrated experiment of magnetizing a ray of light, the idea that electricity is a phenomenon of the ether had been steadily growing, until at last Maxwell perceived that if such were the fact the rate of propagation of an electro-magnetic wave must be the same as the velocity of light. At that time no one knew how to generate such waves, but Maxwell's theory showed him that their velocity must be equal to the number of electric units of quantity in the electro-magnetic unit, and careful experiments

soon proved that that is the velocity of light. Thus it was put almost beyond the possibility of doubt that the ether gives rise to the phenomena of electricity and magnetism as well as to those of light, and perhaps it may even be concerned in the production of gravitation itself. What could be apparently more remote than these electric quantities and the solar parallax? And yet we have here a relation between them, but we make no use of it because as yet the same relation can be far more accurately determined from experiments upon the velocity of light.

Now let us recall the quantities and methods of observation which we have found to be involved either directly or indirectly with the solar parallax. They are, the solar parallax, obtained from transits of Venus, oppositions of Mars and oppositions of certain asteroids; the lunar parallax, found both directly, and from measurements of the force of gravity at the earth's surface; the constants of precession, nutation and aberration, obtained from observations of the stars; the parallactic inequality of the moon; the lunar inequality of the earth, usually obtained from observations of the sun, but recently found from heliometer observations of certain asteroids; the mass of the earth, found from the solar parallax, and also from the periodic and secular perturbations of Venus and Mars; the mass of the moon, found from the lunar inequality of the earth, and also from the ratio of the solar and lunar components of the ocean tides; the masses of all the planets, obtained from observations of their satellites whenever possible, and when no satellites exist, then from observations of their mutual perturbations both periodic and secular; the velocity of light, obtained from experiments with revolving mirrors and toothed wheels, together with laboratory determinations of the index of refraction of atmospheric air; the light equation, obtained from observations of the eclipses of Jupiter's satellites; the figure of the earth, obtained from geodetic triangulations, measurements of the length of the seconds pendulum in various latitudes, and observations of certain perturbations of the moon; the mean density of the earth, obtained from measurements of the attractions of mountains, from pendulum experiments in mines, and from experiments on the attraction of known masses of matter made either with torsion balances or with the most delicate chemical balances; the surface density of the earth, obtained from geological examinations of the surface strata; and lastly, the law of distribution of density in the

interior of the earth, which in the present state of geological knowledge we can do little more than guess at.

Here then we have a large group of astronomical, geodetic, geological and physical quantities which must all be considered in finding the solar parallax, and which are all so entangled with each other that no one of them can be varied without affecting all the rest. It is therefore impossible to make an accurate determination of any one of them apart from the remainder of the group, and thus we are driven to the conclusion that they must all be determined simultaneously. Such has not been the practice of astronomers in the past, but it is the method to which they must inevitably resort in the future. A cursory glance at an analogous problem occurring in geodesy may be instructive. When a country is covered with a net of triangles it is always found that the observed angles are subject to a certain amount of error, and a century ago it was the habit to correct the angles in each triangle without much regard to the effect upon adjacent triangles. Consequently the adjustment of the errors was imperfect, and in computing the interval between any two distant points the result would vary somewhat with the triangles used in the computation—that is, if one computation was made through a chain of triangles running around on the right hand side, another through a chain of triangles running straight between the two points, and a third through a chain of triangles running around on the left hand side, the results were usually all different. At that time things were less highly specialized than now, and all geodetic operations were yet in the hands of first-rate astronomers who soon devised processes for overcoming the difficulty. They imagined every observed angle to be subject to a small correction, and as these corrections were all entangled with each other through the geometrical conditions of the net, by a most ingenious application of the method of least squares they determined them all simultaneously in such a way as to satisfy the whole of the geometrical conditions. Thus the best possible adjustment was obtained, and no matter what triangles were used in passing from one point to another, the result was always the same. That method is now applied to every important triangulation, and its omission would be regarded as proof of incompetency on the part of those in charge of the work.

Now let us compare the conditions existing respectively in a triangulation net and in the group of quantities for the determina-

tion of the solar parallax. In the net every angle is subject to a small correction, and the whole system of corrections must be so determined as to make the sum of their weighted squares a minimum, and at the same time satisfy all the geometrical conditions of the net. Like the triangles, the quantities composing the group from which the solar parallax must be determined are all subject to error, and therefore we must regard each of them as requiring a small correction, and all these corrections must be so determined as to make the sum of their weighted squares a minimum, and at the same time satisfy every one of the equations expressing the relations between the various components of the group.

Thus it appears that the method required for adjusting the solar parallax and its related constants is in all respects the same as that which has so long been used for adjusting systems of triangulation, and as the latter method was invented by astronomers, it is natural to inquire why they have not applied it to the fundamental problem of their own science. The reasons are various, but they may all be classed under two heads. First, an inveterate habit of overestimating the accuracy of our own work as compared with that of others; and, second, the unfortunate effect of too much specialization.

The prevailing opinion certainly is that great advances have recently been made in astronomy, and so they have in the field of spectral analysis and in the measurement of minute quantities of radiant heat; but the solution of the vast majority of astronomical problems depends upon the exact measurement of angles, and in that little or no progress has been made. Bradley with his zenith sector a hundred and fifty years ago, and Bessel and Struve with their circles and transit instruments seventy years ago, made observations not sensibly inferior to those of the present day, and indeed it would have been surprising if they had not done so. The essentials for accurately determining star places are a skilled observer, a clock and a transit circle, the latter consisting of a telescope, a divided circle and four micrometer microscopes. Surely no one will claim that we have to-day any more skilful observers than were Bessel, Bradley and Struve, and the only way in which we have improved upon the telescopes made by Dollond one hundred and thirty years ago, is by increasing their aperture and relatively diminishing their focal distance. The most famous dividing engine now in existence was made by the elder Repsold seventy-

five years ago; but as the errors of divided circles and their micrometer microscopes are always carefully determined, the accuracy of the measured angles is quite independent of any small improvement in the accuracy of the divisions or of the micrometer screws. Only in the matter of clocks has there been some advance, and even that is not very great. On the whole, the star places of to-day are a little better than those of seventy-five years ago, but even yet there is great room for improvement. One of the commonest applications of these star places is to the determination of latitude, but it is very doubtful if there is any point on the face of the earth whose latitude is known certainly within one-tenth of a second.

Looking at the question from another point of view, it is notorious that the contact observations of the transits of Venus in 1761 and 1769 were so discordant that from the same observations Encke and E. J. Stone got respectively for the solar parallax 8.59″ and 8.91″. In 1870 no one thought it possible that there could be any such difficulty with the contact observations of the then approaching transits of 1874 and 1882, but now we have found from sad experience that our vaunted modern instruments gave very little better results for the last pair of transits than our predecessors obtained with much cruder appliances in 1761 and 1769.

The theory of probability and uniform experience alike show that the limit of accuracy attainable with any instrument is soon reached; and yet we all know the fascination which continually lures us on in our efforts to get better results out of the familiar telescopes and circles which have constituted the standard equipment of observatories for nearly a century. Possibly these instruments may be capable of indicating somewhat smaller quantities than we have hitherto succeeded in measuring with them, but their limit cannot be far off because they already show the disturbing effects of slight inequalities of temperature and other uncontrollable causes. So far as these effects are accidental they eliminate themselves from every long series of observations, but there always remains a residuum of constant error, perhaps quite unsuspected, which gives us no end of trouble. Encke's value of the solar parallax affords a fine illustration of this. From the transits of Venus in 1761 and 1769 he found 8.58″ in 1824, which he subsequently corrected to 8.57,″ and for thirty years that value was universally accepted. The first objection to it came

from Hansen in 1854, a second followed from Le Verrier in 1858, both based upon facts connected with the lunar theory, and eventually it became evident that Encke's parallax was about one-quarter of a second too small. Now please observe that Encke's value was obtained trigonometrically, and its inaccuracy was never suspected until it was revealed by gravitational methods which were themselves in error about one-tenth of a second and required subsequent correction in other ways. Here then was a lesson to astronomers who are all more or less specialists, but it merely enforced the perfectly well known principle that the constant errors of any one method are accidental errors with respect to all other methods, and therefore the readiest way of eliminating them is by combining the results from as many different methods as possible. However, the abler the specialist the more certain he is to be blind to all methods but his own, and astronomers have profited so little by the Encke-Hansen-Le Verrier incident of thirty-five years ago, that to-day they are mostly divided into two great parties, one of which holds that the parallax can be best determined from a combination of the constant of aberration with the velocity of light, and the other believes only in the results of heliometer measurements upon asteroids. By all means continue the heliometer measurements, and do everything possible to clear up the mystery which now surrounds the constant of aberration, but why ignore the work of predecessors who were quite as able as ourselves? If it were desired to determine some one angle of a triangulation net with special exactness, what would be thought of a man who attempted to do so by repeated measurements of the angle in question while he persistently neglected to adjust the net? And yet, until very recently, astronomers have been doing precisely that kind of thing with the solar parallax. I do not think there is any exaggeration in saying that the trustworthy observations now on record for the determination of the numerous quantities which are functions of the parallax could not be duplicated by the most industrious astronomer working continuously for a thousand years. How then can we suppose that the result properly deducible from them can be materially affected by anything that any of us can do in a life time, unless we are fortunate enough to invent methods of measurement vastly superior to any hitherto imagined? Probably the existing observations for the determination of most of these quantities are as exact as any that can ever be made with

our present instruments, and if they were freed from constant errors they would certainly give results very near the truth. To that end we have only to form a system of simultaneous equations between all the observed quantities, and then deduce the most probable values of these quantities by the method of least squares. Perhaps some of you may think that the value so obtained for the solar parallax would depend largely upon the relative weights assigned to the various quantities, but such is not the case. With almost any possible system of weights the solar parallax will come out very nearly $8.809'' \pm 0.0057''$, whence we have for the mean distance between the earth and sun 92,797,000 miles, with a probable error of only 59,700 miles; and for the diameter of the solar system, measured to its outermost member, the planet Neptune, 5,578,400,000 miles.

SECTION A.

MATHEMATICS AND ASTRONOMY.

OFFICERS OF SECTION A.

Vice President.

GEORGE C. COMSTOCK of Madison, Wis., EDGAR FRISBY of Washington, D. C., in the absence of Professor COMSTOCK, after Thursday.

Secretary.

JEFFERSON E. KERSHNER of Lancaster City, in the absence of W. C. BEMAN.

Councillor.

R. S. WOODWARD.

Sectional Committee.

EDGAR FRISBY, *Vice President*, 1894, J. C. KERSHNER, *Secretary*, 1894, C. A. DOOLITTLE, *Vice President*, 1893, C. A. WALDO, *Secretary*, 1893, C. H. ROCKWELL, ORMOND STONE, J. A. BRASHEAR.

Member of Nominating Committee.

GEORGE B. HALSTED.

Committee to Nominate Officers of Section.

EDGAR FRISBY, *Vice President*, J. C. KERSHNER, *Secretary*, L. G. WELD, J. BURKITT WEBB, GEO. D. OLDS.

Press Secretary.

GEORGE B. HALSTED.

ADDRESS

BY

GEORGE C. COMSTOCK,

VICE PRESIDENT, SECTION A.

BINARY STARS.

THE Constitution of this Association provides that it shall be the duty of its Vice Presidents "to give an address, each before his respective section," and custom prescribes that the address shall relate to the status and progress of some branch of science falling within the purview of the section. In compliance with this provision it is my pleasure, as well as my duty, to invite your attention for a time to that province of astronomy which comprises double and multiple stars; and if, in considering the development of this province during the past two decades, I shall seem to dwell too much upon matters with which at least a portion of my hearers may be presumed familiar, I trust that the purpose of a vice-presidential address and the circumstances attending it may be considered a sufficient justification for an elementary treatment of the theme.

Attention seems to have been first directed to double stars a little more than a century ago by Christian Mayer, who regarded the faint companion of a more brilliant star as a planet revolving about its primary, and who commenced to form a list of these objects, as being among the notable things of the heavens. His views and his labors brought to Mayer only the ridicule of his contemporaries, and it was not until the micrometric measures of Sir W. Herschel, made for a different purpose, had shown a motion of revolution of the satellite about its primary that the discovery of

double stars and the measurement of their relative positions became a recognized branch of astronomical research.

By far the largest contributions to the early development of double star astronomy were made by the Herschels and the Struves, and the *Mensurae Micrometricæ* of W. Struve, published in 1837, containing accurate measurements of the relative positions of more than 3000 double stars, will long remain the most important contribution made to this branch of science.

The observations of Herschel had established that double stars revolve after the manner of the earth and sun, and had raised a presumption that the law of gravitation determines their motions. Savary, in the early part of the present century, was the first to show that the numerical elements which determine the orbit of a double star, described in accordance with this law, might be derived from observations of the relative positions of the stars made at considerable intervals of time, but the observations available in his day covered too small a period to furnish much information in regard to the orbits. To wait patiently and to accumulate data for future use was the duty of the astronomer of the first half of the present century, and we shall not be wide of the mark if we say that the development of this branch of astronomy from Herschel to our own time is summed up in the words: Discover double stars and measure the relative positions of their components, in order that the future may derive a knowledge of the heavens inaccessible to the present.

We stand to-day upon the threshold of that future,—indeed, we have in some measure entered upon it and are reaping the harvest prepared by a past generation.

In the discovery of double stars the names of Herschel, Struve and Burnham are conspicuous above all others, and it is not a little remarkable that the latter should have been able to find in the heavens more than a thousand new systems of double stars, after Otto Struve had devoted two years to a systematic search for such bodies, in the course of which all of the brighter stars of the northern heavens, some seventeen thousand in number, were carefully examined with the Pulkowa equatorial telescope. Burnham's discoveries are in large part the gleanings from a field already harvested, although his more southern latitude enabled him to search portions of the heavens not conveniently accessible at Pulkowa.

No systematic examination of the southern heavens has yet been made, and one of the desiderata of the present time is such an examination, with a large telescope, of the region within sixty degrees of the south pole. Such an examination would not only furnish a large number of interesting systems for future study, but would complete our at present defective data for a statistical examination of the distribution of these bodies in the heavens.

The foundation of our knowledge in regard to the phenomena of double stars must ever be the data furnished directly by observation of them, the direction and angular distance of one component from another; and the volumes of observations of this kind published within the past two decades indicate, by comparison with the paucity of observations at an earlier epoch, how greatly the interest in double star astronomy has grown.

Passing over the valuable series of observations which are scattered throughout periodical publications and the annals of observatories grateful recognition should be accorded to the cases in which long series of observations by a single astronomer have been collected, discussed and published in an orderly manner, which greatly increases their value to the computer. The work of Otto Struve, Dunér, Dembowski, Hall and Schiaparelli will suggest itself to those familiar with the literature of this branch of astronomy, and it is much to be desired that the work of some of the older observers, such as Mädler and Dawes, might receive a similar editing.

The observations of Dembowski were collected after his death, edited by Otto Struve and Schiaparelli, and published a decade ago by the *Accademia dei Lyncei*. These observations include a remeasurement of all the stars of the *Mensurae Micrometricæ* accessible to Dembowski's instruments, as well as numerous observations of more recently discovered pairs; and aside from their great intrinsic value, they must ever be remarkable as an example of what may be accomplished by zeal and ability, supplemented by very slender instrumental means. An amateur astronomer of infirm health has left, as his memorial to posterity, two volumes containing more than twenty thousand observations of an extraordinary degree of precision, which constitute the largest contribution ever made by one man to the data of double star astronomy.

Of more modest dimensions than the preceding is the volume containing Schiaparelli's observations made at Milan with a tele-

scope of eight inches aperture in the decade 1875–'85. The long introduction to this volume is a veritable treasury of information with regard to the art of observing double stars, and of acute criticism of those sources of error, which like hidden pitfalls, are strewn along the path of the observer. By way of illustration I translate freely from the preface of this work some of Schiaparelli's precepts and remarks:

"In order to avoid every physiological disturbance, I have adopted the rule to abstain for one or two hours before commencing observations from every laborious occupation; never to go to the telescope with stomach loaded with food; to abstain from everything which could affect the nervous system, from narcotics and alcohol, and especially from the abuse of coffee, which I have found to be exceedingly prejudicial to the accuracy of observation." A regimen more suggestive of preparation for an athletic contest than for the more quiet labors of an astronomer.

"The evening twilight is at every season of the year the period in which the best conditions for observing may be anticipated. These conditions sometimes continue for three or four hours, but rarely more than five."

Interesting also is Schiaparelli's estimate of the amount of work which can be accomplished by an observer of double stars within a given period under the favorable skies of Italy. "Dembowski, . . . who was the complete master of his own time, . . . succeeded only once in making more than 2000 measurements in a single year. As for myself, distracted by numerous duties, I have never been able to attain a thousand measures in a year, and I do not think that any observer, however diligent, could ever attain, here, more than 1200 or 1400, since in the entire year there are not more than 300 or 350 hours in which the atmosphere is sufficiently tranquil to permit of such observations and those other labors which require good images and high magnifying powers."

With the above may be compared Vol. 1 of the Publications of the Washburn Observatory, which contains 1090 observations of double stars, made by Mr. Burnham between April 15 and Oct. 1, 1881.

The observations of Otto Struve, contained in Vols. IX and X of the Pulkowa Observations, are of peculiar importance in double star astronomy since, for a large part of the half century over which they extend, they are in great part the only measures avail-

able for a discussion of the motion of binary stars. The observations are preceded by an elaborate historical and critical introduction, devoted largely to a consideration of those errors inherent in the observations, which may be supposed to arise from the mental and physiological peculiarities of the observer. The spirit of this introduction is manifest in the quotation from its author: "However perfect an apparatus may be in its principle, there is no doubt the personality of the observer will affect more or less the results to be obtained with it, and the more perfect the instrument is, the more the observer will feel obliged to deliver also the results from the influence of his own individuality."

This is not the occasion for a technical discussion of the errors affecting the observations of double stars, but the topic is of such fundamental importance, affecting every conclusion which can be drawn from the observed motion of these stars, that no adequate conception of the present state of knowledge concerning them can be formed without constant reference to the character of these errors.

Considered absolutely, the errors are in themselves very minute, and the observations are among the most accurate in the whole range of practical astronomy, but the quantities to be measured, the relative position of the components of a double star, are so minute that an exceedingly small error of observation is frequently a large fraction of the whole quantity measured. The case would not be so bad if these errors were of a fortuitous or accidental character, such that their effect might be eliminated by taking the mean of a large number of observations; but they are not of this character. I quote Schiaparelli's language, somewhat condensed:

"Accidental errors are those which may be expected to occur in observations made at any given time, and include with equal probability equal positive and negative values contained between zero and some maximum limit. They equally affect observations separated by an interval of a few minutes, or days, or months, or years, and their fundamental characteristic is that they may be eliminated by multiplying observations. Such are, for example, errors which arise from the limited acuteness of vision, or from tremors of the star images. Such errors are little to be feared; but it is far otherwise with those errors of a personal character, in part systematic and in part irregularly variable, which have so greatly engaged the attention of the masters of our science. In

the observation of double stars these errors are almost entirely of an individual and physiological character, and consist in a tendency more or less regular to deviate from the truth, always in the same direction. Experience shows that these errors vary in the case of each observer in a manner which can not be expressed by any simple law, changing magnitude, and even sign, at intervals of uncertain duration. The most dangerous of these errors are those which, as in the case of Otto Struve, change their character only with the lapse of a considerable number of years."

When there are strewn in the way of the computer such snares as are presented by errors of this kind, it is manifest that apparent changes in the positions of the components of a double star, which might otherwise lead to important conclusions in regard to the character of its real motion, are all too often to be explained as the product of the different systematic error affecting the work of different observers; *e. g.*, Birkenmajer has shown that the observations of ξ Ursæ Majoris, strongly indicate that the angular diameter of its orbit is increasing, *i. e.*, that the star is rapidly approaching the earth, but it is more than probable that this apparent increase is due to the fact that the systematic error of the modern astronomer is such that on the average he makes his measured distances greater than did the older observers.

The beginnings of the long discussion of systematic errors, which is still far from completion, were made by Bessel and W. Struve. The great heliometer at Königsberg and the equally perfect refractor at Dorpat were both employed for the measurement of a selected list of double stars, with the express purpose of ascertaining whether independent determinations of simultaneous positions of the stars would furnish identical results. The comparison showed a marked difference in the measured distances between the stars, too great and too persistent to be attributed to chance, and each astronomer devised a method for testing his own observations. As not infrequently happens, each reached the apparently well grounded conclusion that his own results were correct, and those of the other wrong, and the lapse of sixty years has not enabled the astronomers of the present day to decide with certainty which observer and instrument were in error.

With regard to the cause of these systematic differences we know virtually nothing, and the mere enumeration of the circumstances which have been shown to affect their character in different ob-

servers will suffice to indicate their complicated nature, *e. g.*, the difference of brightness of the components of a double star; the angle between the direction of the vertical and the line joining the components; the angle between this line and the axis of the observer's head; the magnifying power of the eyepiece employed; the elevation of the star above the horizon; the varying amount of the unsteadiness of the images due to atmospheric tremors; astigmatism of the observer's eyes; the angular distance between the components, etc. Add to the preceding that each one of these causes has been shown to have no effect upon the observations of some particular observer, and that for other observers the effect of many of them has been shown to vary with the lapse of time, and even to change capriciously from night to night, and it becomes apparent that a method for the elimination of these errors is an urgent desideratum.

Numerous methods for their determination have been suggested, the most famous of which is that of the Struves, the measurement of artificial stars having known relative positions. Otto Struve has given an elaborate account of his investigations of this kind, and has derived corrections, first to his own observations, and then, by an indirect process, to the observations of others. While the application of these corrections certainly renders Struve's work more homogeneous, it is doubted by many astronomers whether the resulting data are brought any nearer to the truth. An interesting result of Struve's investigation is that, for position angles, the mean of the corrections to the observations of a considerable number of astronomers is very small; *i. e.*, the personal equation is eliminated by taking the mean of a number of observers. This might have been anticipated *á priori*, and most critics will be disposed to regard it as a confirmation of the investigation rather than as a conclusion resulting from it. On the other hand, Struve's research appears to show that all observers measure the distances between stars systematically wrong, and in such a manner that these errors are not eliminated by taking a mean.

The combination of observations made by different observers and under different circumstances is the principle underlying most of the other methods for the determination of the personal equation, although recourse has been had with varying measures of success to instrumental accessories and to the geometrical conditions involved in the measurement of multiple stars.

From many sources there has come the suggestion that systematic errors of observation may be avoided by a resort to photography, and a deservedly popular essayist in referring to this subject says with enthusiasm:

"All these complications can be at once swept away by substituting the camera for the micrometer. The photographic method leaves no room for systematic, very little for accidental errors." It may be so, but the astronomer who has seen his own observations vitiated by an inexplicable personal error, acquires a moving conviction that the doctrine of total depravity finds application outside the human race, and that the absence of nerves is not a perfect guaranty that a sensitized plate will tell nothing but the exact truth.

What Bond showed nearly forty years ago has been abundantly confirmed during the past decade, and no doubt exists that the wider pairs of double stars may be photographed, and their relative positions determined with great precision, provided the stars are not too unequal in respect of brightness. But at the present time these limitations render the photographic method inapplicable in the very cases where its aid is most desired. In the present state of the art it seems impracticable to apply it to stars separated by a less distance than two seconds of arc, and of the thirty odd binary stars whose periodic times are known to be less than a century, there are only two whose average distance surpasses this limit. Unless marked improvement shall be introduced into the photographic processes, it seems probable that for many years to come our knowledge of the motion of binary stars must depend upon the micrometer, or possibly the interferential refractometer, rather than the camera; and, however great may be the future development of photography, more than a century must elapse before the older micrometric observations can be discarded and the determination of orbits based solely upon photographs. So long as this dependence upon the micrometric measures continues, the personal equations will occupy a position of commanding importance, and the investigations of Bigourdan, in the construction of an apparatus for determining the personal equation under conditions which obviate most of the objections which have been urged against the method of Struve, do not have their value in any way diminished by the introduction of photography. The camera has its own field of usefulness in double star astronomy, and in that field

is quite unrivalled as an instrument of research. We hope that in time it may render the micrometer obsolete, but that time, we believe, has not yet come.

An examination of the periodical literature of astronomy shows that a very considerable amount of industry and acumen has been expended during the last quarter of a century in devising methods for computing the orbit of a double star. In so far as these methods have a common tendency toward a particular mode of treatment, this may be said to lie in the increased scope given to graphical methods. These were indeed early introduced by Sir John Herschel, to whom is also due the graphical adjustment of the data furnished by the observations, as well as the principle, now falling into some disfavor, of employing measurements of distance solely for the determination of the dimensions of the orbit, deriving all of the other elements from the position angles.

The assumed inferior precision of the measurements of distance, which was the ground for this discrimination, was probably true in the case of the Herschels and South, and to a much less degree in the case of W. Struve. But Otto Struve showed in 1878 that his distance measures were slightly more precise than his position angles, and Burnham and others have more recently emphasized the equal value of the coördinates in the determination of the orbits. To this view there is opposed the opinion of a considerable body of astronomers, who maintain that so long as a comparison of observations by different observers shows greater discrepancies in the distances than in the position angles, as is the case at the present time, so long will it be necessary to base the determination of orbits as far as possible upon the position angles, which are shown to be less affected by systematic error, although in respect of accidental error they present no marked superiority.

It is probably safe to say that at the present time we do not possess a definitive orbit of any binary star, and many of the orbits which have been computed can not be regarded as even first approximations to the paths they purport to represent. During the past two years, the periodical literature of astronomy has presented a number of interesting cases in which totally different orbits have been derived from the same data. In most of these and similar cases, the data are of rather limited amount; but it is by no means impossible to cite instances in which motion through

half a revolution, or even more, has proved insufficient to determine the true form of the orbit.

It is instructive to note in this connection how different are the circumstances which attend the determination of the orbits of a binary star and of a planet, an asteroid for example. In the case of the asteroid the observations have been made from a moving standpoint, the earth, and its displacement within a few days is sufficient to furnish a base line from which the distance of the planet may be determined with considerable precision. This determination carries with it a knowledge of the distance and direction of the planet from the sun, and therefore the intensity and direction of the central force acting upon it. All that is further required for the determination of the orbit is the direction and velocity of the motion at a given moment, and the orbit of a planet therefore may be at least approximately determined from observations extending only over a few days. In the case of the binary star, its distance from the earth is such that all hope of using the motion of the latter as a base line must be abandoned. The distance between the components of a double star and the intensity of the force under which they move remain completely unknown; and the character of the path in which the components move must be determined by watching that motion through a considerable fraction of a revolution, and in case the plane of the orbit is but little inclined to the line of sight, an indefinite number of whole revolutions may not suffice for the determination of all of the elements of the orbit.

To attempt to define the precise fraction of a revolution through which the components of a double star must be observed before a satisfactory orbit can be computed, would be as vain as to attempt the definition of the number of grains of sand which are requisite to constitute a heap; but with some rough approximation to the truth we may say that orbits based upon motion through less than half a revolution, are for the most part ill determined. Since observations of double stars began but little more than a century ago, our knowledge of their orbits is, for the most part, confined to those whose periods of revolution do not exceed two hundred years. Periodic times greater than this must be quite uncertain, although some of the elements of the motion may be fairly well determined.

There have been published to the present time orbits of forty-

two binary stars, each based upon a motion of more than 180°. The elements of these orbits, together with those of a few other stars in which the motion is but little less than half a revolution, are appended to this paper.

Writing in 1877, Gyldén could say: "At present the shortest known periodic time in a binary system is that of 42 *Comæ*, which amounts to a little more than twenty-five years;" but discovery in the intervening years has been so rapid that in our list of forty-four well determined orbits, 42 *Comæ* ranks tenth instead of first in respect of periodic time. At the head of the list stand δ *Equulei* and $\varkappa$ *Pegasi*, each with a period slightly less than a dozen years.

These orbits are all computed upon the assumption that the components of a double star have their respective paths determined by the Newtonian law of gravitation. That this assumption is in fact true is not seriously doubted at the present time by any astronomer, but it must be confessed that no satisfactory demonstration of it has been given, and from the data available it does not appear probable that one ever can be given. In response to a problem proposed by Bertrand, Darboux and Halphen have independently derived mathematical expressions for the laws of force which must obtain in order that two bodies subject to no other accelerating force than their own mutual attraction shall necessarily describe conics about each other. There prove to be two such laws of force, and if we add to the statement of the problem the further condition that the intensity of the force shall depend upon the distance, but not upon the direction of one body from the other, the two laws admit of the simple statement that the force must be either proportional to the mass multiplied by the first power of the distance, or to the mass divided by the square of the distance. Since the first of these laws would lead to an infinite force between finite bodies placed at an infinite distance from each other, it can have no physical significance, and we may safely conclude that if the true orbits of binary stars are elliptical, then the law of force must be either the Newtonian law or, very improbably, a force whose intensity depends upon the direction of the line joining two bodies, as well as upon the masses and distances.

The apparent orbits of the stars may easily be shown to be very approximately elliptical. The seemingly insuperable obstacle to a demonstration for these bodies of the law of gravitation lies in the proof that the real orbits are also conic sections.

The absence of a rigorous demonstration of the law of force has not precluded a study of the perturbations which exist in multiple systems. There are many such systems in the heavens which present the problem of three bodies in its most general form, and without any of those limitations, upon which all of the known solutions of the problem are based: "Nature here challenges the mathematicians." But cases also occur, like that of ζ *Cancri* in which the relations among the mutual distances of the bodies are such as to admit the application of those partial solutions of the problem which we possess, and the theory of perturbations begins to find its application in these cases.

Herschel in 1781 first recognized ζ *Cancri* as a triple star, consisting of two components A and B, separated by about a second of arc, and a third component, C, distant about 6″ from the others.

Otto Struve and Flammarion seem to have discovered almost simultaneously, some twenty years ago, that while the relative motion of A and B is of the ordinary elliptical character, C moves in a manner difficult to reconcile with a purely elliptical orbit, but which strongly suggests a succession of loops, similar to those of an epicycloid. The explanation lay near at hand that this star is attended by an invisible companion, producing a motion of revolution about their common center of gravity, which, combined with a motion about the stars AB, would furnish a sufficient explanation of the epicycloidal loops. The arc moved over by the star C since its discovery is quite too small to determine its orbit about AB, but from a critical examination of the empirical formulæ which in such cases serve as a temporary substitute for a knowledge of the orbit, Seeliger finds that the position angles, and the distances of the stars indicate independently of each other a revolution of C such as would be produced by an invisible companion. At this point an application of the theory of perturbations was for the first time introduced into double star astronomy, with the result that the peculiar motion of the star C cannot be produced by any disturbance due to A and B, although it profoundly modifies their motion.

Some of the results of Seeliger's investigations are as follows: The peculiar motion of the star C *is* due to the presence of an invisible companion, whose angular distance from C does not exceed a few tenths of a second of arc, and whose mass does not differ very greatly from that of C. The plane of the orbit described by

C and its dark companion is approximately parallel to the plane of the orbits of A and B, thus offering an interesting analogy with the solar system. The combined mass of C and its companion can not be less than one-fifth the sum of the masses of A and B, but no superior limit to the masses can at present be assigned. For a long period of time the perturbations produced in the system will be confounded with the elliptical elements of the relative motions, and cannot be determined from the observations of the stars, but this condition can not continue indefinitely, and it will ultimately be possible to separate between the perturbations and the undisturbed motion. The elements of the motion of A and B about their common center of gravity and the elements of C and its companion are given in the table appended to this paper.

The hypothesis of invisible stars did not originate in the case of *ζ Cancri*. Its first suggestion, as an explanation of the anomalous behavior of visible stars, came from Bessel, and his investigation of the irregular motions of Sirius and Procyon is well known. The dark companion of the latter star remains invisible to the present day, although the researches of Auwers and L. Struve have established its existence beyond a reasonable doubt. The dark companion of Sirius was transferred by Clark, in 1862, into the category of things seen. There is at the present time some difficulty in reconciling the motion of the visible star with that assigned by the computations of Auwers to the invisible one, and it is even possible that the two are not the same body, but this uncertainty cannot long continue, for the companion, which for some years has been lost to sight, owing to proximity to Sirius, must soon emerge from his rays, and a single observation after the peri-astron passage may be expected to solve the difficulties which now attend the case.

Stars known to exist though never seen grow commonplace with the development of astronomy. From his photographs of 61 *Cygni*, Wilsing has recently found reason to believe that this famous double star is attended by an invisible companion, whose presence is revealed by its disturbing action upon the visible ones. The spectroscopic work of Vogel has confirmed the supposition that the variable brilliancy of Algol is due to the presence of a dark satellite, and for the first time has determined the linear dimensions of a fixed star, which prove to be not very different from those of the sun. There is even some probability of a second satellite to Algol

being required in explanation of some peculiarities of its variability and motion.

In these dark companions there begins to be manifest a peculiarity of no small interest and significance. The light of Sirius exceeds that of its companion ten thousand fold, but its mass is only twice as great. The invisible star in ζ *Cancri* has approximately the same mass as the visible ones. The dark companion of Algol is nearly as large as Algol itself, and if these are typical cases, the equality of mass thus indicated has an important bearing upon theories of stellar development.

The spectroscopic work of very recent years has produced a new class of binary stars, whose existence is revealed by a periodic displacement or doubling of the Fraunhofer lines in the stellar spectra. Such a doubling, being due to motion of the components of the star in opposite directions along the line of sight, can attain a perceptible amount only in the case of very great velocities, produced by a combination of such favorable circumstances as great mass, close proximity of the stars and small inclination of the orbit plane to the line of sight. Under these conditions the ordinary visual methods of detecting and observing double stars fail, and the spectroscopic method is therefore to be welcomed as a most valuable complement to the methods hitherto in use, rendering possible the investigation of the motions of stars in such close proximity as to be beyond the separating power of a telescope ten fold more powerful than any now in existence. Four stars of this class are at present known, not including several doubtful or suspected cases.

Another new class of binaries, in some respects similar to the spectroscopic pairs, is suggested by the explanation of the changing brightness of variable stars furnished by Mr. Lockyer as a part of his Meteoritic Hypothesis; an explanation so elegant and simple that in the absence of conclusive proof we are constrained to say of it: *Se non è vero, è ben trovato.*

Methods for the computation of orbits from spectroscopic measurements have been published by Rambaut and Wilsing, and from the illustrative examples accompanying these papers I reproduce the following elements, which, although presumably rough approximations, are interesting as being the first orbits ever derived from spectroscopic measures alone.

Star	e	λ	P	T
β Aurigæ	0.16	57°	3.968 days,	1889, Dec. 3.21
α Virginis	0.02	266	4.013 "	" Apr. 18.12

The spectroscopic observations are incapable of determining the remaining elements of the orbits, but they furnish a relation between the dimensions of the orbit and its inclination to the line of sight, which may be employed for the determination of a minimum value for the mass of the stars. The mean value of this inferior limit for the four spectroscopic binaries is two and a half times the mass of the sun.

Conceding that the law of gravitation is fully applicable to binary stars, and that no third body is present to produce perturbations, it by no means follows that the observed motion of a binary star will be in conformity with the theoretical motion of two bodies subject only to their individual attractions. Savary was the first to call attention to what are now known as optical inequalities in the motion of binary stars, *i. e.*, inequalities depending upon the finite velocity of light, and to point out, with some errors subsequently corrected by Villarceau, a relation between these inequalities and the parallax of the star. Since the components of a double star are in general at unequal distances from the earth, the rays of light from them which at any moment enter the eye of the observer do not correspond to simultaneous positions of the stars, but the farther star will appear less advanced in its orbit than the nearer one, since the light left it at an earlier epoch. The larger the orbit and the smaller its inclination to the line of sight, the greater will be the effect thus produced, and Savary hoped to determine from this effect the absolute dimensions of the orbit, and the distance of the star from the earth. Other optical inequalities may be produced by the changing distance of the star from the earth (proper motion) and by different intensity in the light of the two components. The theory of these inequalities has been succinctly set forth by Seeliger, and may be summed up as follows:

The effect of proper motion is to produce small changes in the elements which determine the position of the orbit in space, but since these variations remain constant so long as the proper motion is constant, they are confounded with the elements of the orbit, and furnish no information with regard to the star. If light of different intensities is transmitted through space with different velocities, a supposition by no means established, then a binary star whose components are of very different brightness will present optical inequalities in its motion, due to the difference in the velocity of propagation of the light emitted by the two bodies. It is, however,

hardly credible that these inequalities should be of sufficient magnitude ever to be detected. The only remaining inequality, however, offers more of interest, since it leads to a relation between the relative masses of the components of a binary star and their parallax or distance from the earth. If the masses are unequal and if the plane of the orbit be but little inclined to the line of sight, Kepler's law of areas will not hold true in the apparent orbit of the star, but the deviations from the law may be fully taken into account by applying to the dates of the observations periodic corrections, depending upon the positions of the stars in their orbit. The constant coëfficient of these corrections involves, as the only unknown quantities, the ratio of the masses of the two components and the linear dimensions of the orbit. The larger the orbit, the less its inclination to the line of sight, and the greater the disparity of the masses, the larger will be the resulting inequality in the motion, and it is by no means improbable that this inequality may be found of sensible magnitude in the case of some binaries. Whenever it is found sensible it may be made to furnish a determination of the parallax of the star, since the relative masses of the components can be ascertained by referring the motion of each of them to neighboring stars which do not belong to the system. The line of investigation thus indicated is of especial interest since, from the manner in which the unknown quantities are involved, it offers a method of determining parallaxes too minute to be obtained in any other way.

A beginning of such investigations has been made by Birkenmajer, who has endeavored to determine from the observations of *ξ Ursæ Majoris* the coëfficient of its optical inequality. Although the relative brightness of its components is only as 1 to 4, and a very great disparity of the masses seems rather improbable, Birkenmajer finds with some degree of probability a positive coëfficient of the inequality whose value does not differ greatly from one degree, or expressed in time, sixty days.

Three-quarters of a century ago Bessel pointed out a dynamical relation connecting the mass of a double star with its parallax and the elements of its orbital motion. The elements having been determined, the hypothesis that the combined mass of the components equals the mass of the sun furnishes a "hypothetical parallax." In Bessel's time this hypothesis was an entirely gratuitous one, but the lapse of years has brought a determination of the parallaxes,

as well as the orbits of a number of binary stars, and we now possess at least the beginnings of a knowledge with regard to the masses of the heavenly bodies. Omitting uncertain determinations of very small parallaxes, and including results from the spectroscopic binaries, the substance of what is known in this direction is contained in the accompanying table. The periodic time of 61 *Cygni* is so uncertain that it should perhaps be omitted.

Star.	Time of revolution.	Semi-axis major.	Hypothetical parallax.	Observed parallax.	Mass of the system.
		″	′	″	
α Centauri, . .	81.1 yrs.	17.70	0.94	0.75	2.0
61 Cygni, . . .	782.6 "	29.5	.35	.43	0.5
Sirius, ...	49.4 "	7.57	.56	.38	3.2
η Cassiopeæ, .	148.9 "	8.79	.31	.20	3.8
o² Eridani, . .	139.0 "	5.99	.22	.19	1.6
70 Ophiuchi, .	88.4 "	4.60	.23	.15	3.7
β Aurigæ, . .	4 days	*	*	*	> 4.6
α Virginis, . .	4 "	*	*	*	> 2.6
ζ Ursæ Majoris.	105 "	*	*	*	> 2.3
Algol, ...	3 "	*	*	*	> 0.7

*Spectroscopic binary.

Although the amount of data is insufficient to support very much generalization, some of its indications are worth noting. The masses of the visual and of the spectroscopic binaries are derived by wholly different methods, but both classes of bodies indicate that the sun is an undersized star, a result which is confirmed by other and independent lines of investigation. The small range of values presented by the masses of the stars is remarkable, and points to an unexpected uniformity of size in the heavenly bodies, the average component of a double star having a mass somewhat greater than the mass of the sun. It is probable that, on the average, hypothetical parallaxes would correspond a little more closely to the actual distances of the stars if the assumption in regard to mass were modified in the direction thus indicated; but, for the sake of uniformity, it will doubtless be well to retain Bessel's hypothesis for the present at least, but to regard it as furnishing parallaxes which require to be diminished by approximately one-fifth part, in order to bring them into conformity with the present state of knowledge.

While for any particular star the hypothetical parallax must be regarded as an uncertain index of distance from the earth, it seems entitled to more confidence when applied to statistical inquiries with regard to the average properties of groups of stars, and large additions to our knowledge concerning the constitution of the heavens may be anticipated, as a consequence of increasing data of this kind. For the present the amount of this data is insufficient to support any certain conclusions from it, but its indications may be of interest as pointing the way for future research. Thus: the fainter stars are commonly assumed to be more distant from the earth than are the brighter ones, but the hypothetical parallaxes of binary stars either indicate no increase of distance with diminishing brightness, or an increase in much smaller degree than is required by the light ratio, 2.5, between consecutive stellar magnitudes.

If binary stars are classified with respect to their type of spectrum, it will be found that on the average the distance of a star possessing a Sirian spectrum is about three times as great as that of a star possessing a solar spectrum, and it will further be found that although stars of the Sirian type are on the whole more numerous than solar stars, binaries of the solar type outnumber their Sirian fellows three to one. Have the causes which determine stellar evolution produced an excess of double stars in our province of the universe, or have we merely found a larger percentage of those which are near us?

With respect to the average dimensions of double star orbits, the hypothetical parallaxes lead to the conclusion that of the binary stars which have periods of less than two centuries, four-fifths move in orbits smaller than that of Neptune, while the most rapidly moving visual binaries have orbits intermediate in size between those of Jupiter and Saturn.

It must be understood that conclusions such as these are only present indications which require for their confirmation a larger body of data than is now attainable.

Mass and distance do not suffice to determine even the apparent qualities of a star, and if we consider the intrinsic brightness of these bodies, or "candle power per ton," as Professor Young calls it, we shall find a very different set of circumstances. Monck has pointed out a relation by which the measured amount of light received from a binary star, together with the elements of its orbit, may be made to furnish a determination of its "mass brightness"

in terms of an arbitrary standard. While it is doubtful if this "mass brightness" corresponds to any determinate physical quality of the stars, the numbers derived by Monck are interesting in that they indicate a wide diversity among binary stars, which is presumably an index to differences of physical condition. Thus the mass brightness of γ *Leonis* is more than a thousand times that of 61 *Cygni*, a result which must be accepted with much reservation, since the orbit of neither star is at all well determined. If we confine our attention to those binaries whose orbits may be considered fairly well determined, we find at the extremities of the list φ *Ursæ Majoris* with a mass brightness fifty times that of 70 *Ophiuchi*. The mass brightness of the sun is probably not much greater than that of 70 *Ophiuchi*.

The suggestion is often made that the distances of binary stars from the earth may be determined by using the spectroscope to measure the motion of the components in the line of sight. In the case of the recently discovered spectroscopic binaries, whose periods of revolution are measured by a comparatively small number of days, this has been accomplished in so far as the spectroscopic measurements are concerned; but no parallax can be determined from these observations at the present time, since it is impossible to measure the angular distance between the component stars on account of their extreme proximity. It is not improbable that the method may be successfully applied to some of the more rapidly moving visual binaries, *e. g.*, *α Centauri*, but that it admits of general application in the present state of science seems more than doubtful.

A motion of a mile per second may be considered as standing near the limit of the power of the spectroscope, even when aided by the camera, and while a considerable number of the more rapidly moving binaries will furnish velocities along the line of sight, somewhat exceeding this limit, it will probably be in exceptional cases only that they will admit of measurement. It is unfortunate for the application of this method to binary stars that the rapidly moving, and therefore most interesting, stars are for the most part in such close proximity that the two spectra furnished by the components will blend into one.

Scarcely inferior in interest to the determination of parallaxes, should improved spectroscopic methods permit of this use, will be the determination of the position in space of the orbit planes of

the stars. Micrometric measures suffice to determine the angle between these planes and the line of sight, but are unable to determine which half of the orbit lies nearer to the observer. A single determination of the direction of motion along the line of sight will remove this ambiguity and completely determine the position of the plane.

The special interest of such determinations lies in their bearing upon our broader theories of the genesis of the stellar system. That the aggregation of stars along the Milky Way is a consequence of causes operating in past time cannot well be doubted, and it is equally apparent that the orbital motions of double stars have been similarly produced. Do these motions sustain any peculiar relation to the Milky Way or to each other? Is there a tendency for the poles of the orbits to cluster in any definite region of the heavens? Is there any uniformity in the direction of orbital motion? Such are some of the questions whose solution depends upon a complete determination of the positions of the orbit planes.

It has long been known that if the components of a double star are of approximately equal brilliancy, they are of the same color, and if of unequal brilliancy the color of the fainter companion lies nearer to the violet end of the spectrum than does the color of the brighter one. The spectra of the stars furnish a partial explanation of their difference in color by showing in at least some cases that the stars possess spectra of different types, the fainter companion having a Sirian and the brighter a solar spectrum.

In the case of a double star whose components are of unequal magnitude, but too close to be separately seen, it is evident that the two spectra would be superposed, the result being a composite spectrum intermediate between the solar and Sirian types. Professor Pickering has suggested that in at least some cases the presence of a spectrum of this character should be regarded as an indication of duplicity, and has further suggested that in the case of rapid revolution of the star there will be a displacement of the characteristic hydrogen lines relative to the remainder of the spectrum by which to verify the duplicity. The most conspicuous instance of such a composite spectrum is furnished by Procyon, and Pickering has found from measurements of its spectrum a small displacement of the lines. It remains for future research to show whether this displacement is periodically variable, as it should be if it arises from orbital motion of the components of a double star.

I have said that differences of spectral type furnish a partial explanation of the observed differences of color. It would perhaps, be more proper to say that these differences furnish a new and exceedingly puzzling series of problems. A Sirian star is supposed to possess a higher temperature than a star of the solar type, and this view is corroborated in the case of binaries by the application of Monck's formula for mass brightness, which shows that on the average the mass brightness of a Sirian star is about five times that of a star of the solar type. But shall we believe that in case of unequal brightness in the components of a double star the fainter companion is always the hotter and the more luminous in proportion to its mass? Or shall we conclude that a Sirian spectrum does not imply a higher temperature than one of a different type? It is possible that the difference in color is apparent, rather than real, and arises from physiological causes, but this does not seem altogether probable. A systematic examination of the spectra of these bodies, more complete than has yet been published, would be especially welcome for the elucidation of these problems.

Few researches upon double stars exceed in theoretical interest the mathematical investigations of Mr. See, with regard to the mode of development of these bodies. As early as 1878 Doberck had shown from a statistical comparison of double star orbits that in general the longer the period of revolution of the components, the larger and more eccentric are their orbits. That the orbits should be larger might have been expected as a consequence of the law of gravitation, but it required a special investigation based upon the theory of tidal friction, as developed by Prof. G. H. Darwin, to show that the increasing eccentricities are also a necessary consequence of the same law. The conclusions of Mr. See may be briefly summarized as follows: If we suppose the components of a double star to be composed of a plastic material, they will produce in each other bodily tides, whose effect will be to push the stars asunder, and at the same time to increase the eccentricity of their orbits. This increase of eccentricity will not continue indefinitely, but in the later stages of development will give way to a diminution of the eccentricities, which will ultimately produce circular orbits. But since the energy of the star is being constantly wasted by radiation, it will in the later stages of its career be reduced to invisibility, and during the period of its existence as a luminous body its history will present a continuous increase in the size and

eccentricity of its orbit. It is of interest to note in this connection that the two orbits of spectroscopic binaries which have been computed present eccentricities very much less than that of the average double star orbit, while the dimensions of their orbits are so small as to suggest an early stage in the development of the systems.

The ultimate problem of the astronomer is to furnish a rational account of the structure of the heavens, of the course of development by which that structure has been produced, and of the future states towards which it tends. The relations to this broader field which are sustained by the problems of double star astronomy have been more than once touched upon in this brief sketch. The importance of these problems in the construction of a rational cosmology will not be questioned by the competent critic, and we have no desire to magnify their importance by belittling cognate lines of research. Let it suffice that he whose work has lain along these lines be counted among those who have conjoined in rolling back the veil of ignorance from the face of nature, and in presenting her to his fellow-men as a cosmos whose law and order are known.

ORBITS OF BINARY STARS.

Star.	R. A.	Dec.	Mags.			Latest Obs.	Amount of Motion.	Computer.	Publication.
	h								
Σ 3062	0.0	58°		6.9	8.0	1877	340°	Doberck	Astr. Nach. 2277
Σ 2	0.1	79		6.3	6.6	1892	180	Glasenapp	Astr. Nach. 3145
γ Androm. BC	1.9	42	3.0	5.0	6.2	1883	360	Burnham	M. N., R. A. S. Dec. 1883
20 Persei	2.8	38		5.3	6.5	1891	240	Glasenapp	A. and A-P. 116
40 o^2 Eridani BC	4.2	— 8	4.0	9.1	10.8	1883	210	Gore	M. N., R. A. S. March, 1886
β 883	4.7	11		7.5	7.8	1891	290	Glasenapp	Astr. Nach. 3119
Sirius	6.6	—17	—	1.4	9.0	1890	> 360	Auwers	Astr. Nach. 3085
Procyon	7.6	5		0.5	....	....	....	L. Struve, Auwers	V. J. S. 19. (Review)
9 Argûs	7.8	—14		5.7	6.3	1892	170	Burnham	A. and A-P. 116
ζ Cancri AB	8.1	8		5.0	5.7	1888	340	Seeliger	Fortgesetzte Untersuchungen,
ζ Cancri CD	8.1	8		5.5	....	1888	1200	Seeliger	etc. Munich, 1888
Σ 3121	9.2	30		7.5	7.8	1891	240	Celoria	Astr. Nach. 2808
ω Leonis	9.4	10		6.2	7.0	1892	350	Hall	Astr. Jour. 269
φ Urs. Maj.	9.7	55		5.5	5.5	1892	250	Glasenapp	Astr. Nach. 3119
ξ Urs. Maj.	11.2	32		4.0	4.9	1879	360	Birkenmajer	K. Akad. Wiss. Wien, Bd. 93
O Σ 234	11.4	42		7.0	7.4	1886	180	Gore	Astr. Nach. 2743
γ Virginis	12.6	— 1		3.0	3.0	1881	330	Doberck	Copernicus, I, 148
γ Centauri	12.6	—48		4.0	4.0	1890	350	Gore	M. N., R. A. S. May, 1892
42 Comæ	13.1	18		6.0	6.0	1874	720	O. Struve	M. N., R. A. S. May, 1875
25 Can. Ven.	13.5	37		5.0	8.5	1880	290	Doberck	Astr. Nach. 2345
O Σ 269	13.5	35		7.2	7.7	1891	360	Gore	M. N., R. A. S. June, 1892
α Centauri	14.5	—60		1.0	3.5	1883	350	See	M. N., R. A. S. Dec., 1893
O Σ 285	14.7	43		7.5	7.6	1892	270	Burnham	A. and A-P. 117
η Cor. Bor.	15.3	31		5.2	5.7	1892	550	Comstock	Unpublished
μ^2 Bootis	15.3	38	4.0	6.7	7.3	1878	220	Doberck	Astr. Nach. 2194
O Σ 298	15.5	40		7.0	7.4	1887	320	Celoria	Astr. Nach. 2843
γ Cor. Bor.	15.6	27		4.0	7.0	1887	350	Celoria	Astr. Nach. 2904
ξ Scorpii AB	16.0	—11		4.9	5.2	1889	200	Schorr	Thesis
σ Cor. Bor.	16.2	34		5.0	6.1	1876	210	Doberck	Astr. Nach. 2103
ζ Herculis	16.6	32		3.0	6.5	1880	630	Doberck	Astr. Nach. 2332
β 416	17.2	—35		6.4	7.8	1892	220	Gore	M. N., R. A. S. March, 1893
Σ 2173	17.4	— 1		5.8	6.1	1876	360	Dunér	Étoiles Doubles
μ Herculis BC	17 7	28	3.8	9.5	10.5	1894	332	Hall	Astr. Jour. 324
τ Ophiuchi	17.9	— 8		5.0	5.7	1875	280	Doberck	Astr. Nach. 2196
70 Ophiuchi	18.0	3		4.1	6.1	1893	500	Schur	Astr. Nach. 3220-21
99 Herculis	18.0	31		5.7	11.5	1890	300	Gore	M. N., R. A. S. Nov., 1890
ζ Sagittarii	18.9	—30		3.9	4.5	1892	200	See	A. and A-P. 116

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NOTE.—The column headed Latest Obs. shows the date of the latest observation included in the determination of the orbit.

Star.	Ω	i	λ	e	a	P	T	Hypothetical Parallax.	Spectrum D. C.
	°	°	°		"	y		"	
Σ 3062	39.1	32.2	92.1	0.45	1.27	102.9	1835.5	0.05	F
Σ 2	154.9	70.2	43.9	.40	0.55	166.2	1890.9	.02	A
γ Androm. BC	113.5	78.9	200.8	.88	0.37	54.8	1892.1	.02	K
20 Persei	133.0	73.6	263.7	.48	0.25	20.8	1885.0	.04	F
40 o^2, Eridani BC	146.3	76.3	354.4	.14	5.99	139.0	1863.9	.23	H ?
β 883	69.7	28.5	155.0	.48	0.24	16.4	1874.1	.04	A
Sirius	37.5	42.4	39.9	.63	7.57	49.4	1844.2	.58	A
Procyon	....	[0.]	....	[.0]	0.70*	39.9	1795.0	....	F
9 Argûs	95.7	76.9	73.9	.68	0.61	23.4	1892.7	.08	E
ζ Cancri AB	80.2	11.1	109.7	.38	0.86	59.1	1868.1	.06	F
ζ Cancri CD	199.0	17.4	109.7	.11	0.22*	17.6	1860.1	.06	F
Σ 3121	24.8	75.4	129.5	.81	0·67	34.6	1878.5	.06	E
ω Leonis	147.1	64.2	122.9	.54	0.86	115.3	1842.0	.03	E
φ Urs. Maj.	165.7	34.7	19.0	.45	0.29	91.9	1885.4	.01	A
ξ Urs. Maj.	280.7	122.9	305.8	.41	2.55	60.5	1814.8	.17	G
O Σ 284	124.2	47.4	73.0	.36	0.34	63.5	1881.2	.02	E
γ Virginis	46.0	33.2	98.9	.89	3.94	179.6	1836.4	.12	F
γ Centauri	178.0	84.1	46.8	.63	1.50	61.9	1840.8	.10	A
42 Comæ	11.0	90.0	99.2	0.48	0.66	25.7	1869.9	.07	F
25 Can. Ven.	42.4	33.3	245.0	.72	0.81	119.9	1868.0	.03	A
O Σ 289	51.9	89.8	43.5	.06	0.58	47.7	1883.1	.04	A
α Centauri	25.5	79.7	51.6	.52	17.70	81.1	1875.6	.90	G
O Σ 285	54.3	44.3	180.0	.43	0.39	62.1	1885.3	.02	F
η Cor. Bor.	26.9	55.0	220.5	.33	0.86	41.6	1892.3	.07	F
μ^2 Bootis	173.7	40.0	20.0	.60	1.47	280.3	1863.5	.08	B
O Σ 298	2.1	65.8	21.9	.58	0.88	56.6	1889.9	.06	G
γ Cor. Bor.	118.5	81.7	250.7	.35	0.63	85.3	1840.5	.03	A
ξ Scorpii AB	10.5	67.6	102.6	.12	1.31	105.2	1862.3	.06	F
σ Cor. Bor.	16.5	31.9	73.8	.75	5.88	845.9?	1826.9	.07	E
ζ Herculis	41.7	43.2	252.7	.46	1.28	34.4	1864.8	.13	G
β 416	139.4	56.7	278.3	.56	2.13	34.5	1891.8	.21	Q
Σ 2173	152.6	80.5	7.3	.13	1.01	45.4	1879.9	.08	F ?
μ Herculis BC	62.6	63.3	183.9	.17	1.36	42.1	1880.4	.11	I
τ Ophiuchi	65.4	58.7	41.4	.61	[1.19]	217.9	1821.9	.03	F
70 Ophiuchi	121.3	60.1	168.3	.48	4.60	88.4	1808.1	.23	K
99 Herculis	50.1	38.6	110.7	.79	1.12	53.6	1885.6	.08	F
ζ Sagittarii	75.4	74.0	327.4	.30	0.68	17.7	1878.6	.11	A

*Semi-axis major of the orbit of the visible star. This should be multiplied by $(1+m)$ where m is the mass of the dark companion, in order to obtain the dimensions of the relative orbit.

Star.	R. A.	Dec.	Mags.	Latest Obs.	Amount of Motion.	Computer.	Publication.
γ Cor. Aust.	19.0	—37	5.5 5.5	1891	220	Sellors	M. N., R. A. S. Nov. 1892
Σ 2525	19.4	27	7.4 7.6	1892	290	Gore	M. N., R. A. S. Nov. 1892
O Σ 400	20.1	44	7.3 7.7	1885	200	Gore	M. N., R. A. S. April, 1887
β Delphini	20.5	14	3.5 4.5	1892	340	Glasenapp	Astr. Nach. 3177
4 Aquarii	20.7	— 6	5.9 7.2	1877	190	Doberck	Astr. Nach. 2287
δ Equulei	21.1	10	4.5 5.0	1883	980	Wrublewsky	Astr. Nach. 2771
κ Pegasi	21.7	25	3.9 10.8	1892	360	Glasenapp	M. N., R. A. S. June, 1892
85 Pegasi	23.9	26	6.0 11.1	1888	213	Schæberle	Astr. Jour. 185

Star.	Ω	i	λ	e	a	P	T	Hypothetical Parallax.	Spectrum D. C.
γ Cor. Aust.	58.0	35.6	181.1	0.33	2.19	121.2	1879.3	0.09	F
Σ 2525	78 3	54.0	4.3	.80	0.75	138.5	1887.1	.03	F?
O Σ 400	146.3	37.9	43.5	.67	0.59	170.4	1882.1	.02	F?
β Delphini	174.4	64.6	344.2	.28	0.51	24.2	1882.4	.06	F
4 Aquarii	340.2	56.6	235.0	.46	0.72	129.8	1752.0	.03	A
δ Equulei	24.0	81.8	26.6	.20	0.41	11.5	1892.0	.08	F
κ Pegasi	125.7	66.0	199.9	.20	0.21	11.5	1898.8	.04	F
85 Pegasi	306.1	68.6	70.3	.35	0.96	22.3	1884.0	.12	E

NOTE.—I am indebted to Prof. E. C. Pickering for the types of spectrum of ten stars not contained in the Draper Catalogue.

PAPERS READ.

AN EXTENSION OF THE GAUSSIAN POTENTIAL THEORY OF TERRESTRIAL MAGNETISM. By L. A. BAUER, Berlin, Germany. (Read by Prof. R. S. WOODWARD.)

[ABSTRACT.]

IN the course of our terrestrial magnetic investigations the question came up whether the potential of terrestrial magnetic force at the earth's surface could be derived, according to the Gaussian potential theory of terrestrial magnetism, for epochs where force observations are wanting and but observations of declination or of inclination or of both were at hand. If this potential could be derived, say for epochs 1600, 1700, etc., up to the present time, a secular variation term might be introduced in the Gaussian potential expression, and thus an expression obtained which would permit the drawing of approximate magnetic charts for any time during the interval for which the formula had been established and various other interesting questions answered, as, *e. g.*, what is the orbit described by the magnetic pole in the course of centuries?

As the poles are the points of the earth's surface where the potential would have a maximum or minimum value, by subjecting the potential expression to this condition, the points might be located for any particular epoch.

The above question has been partially investigated and affirmatively answered. Roughly outlined it is as follows: —

Let X, Y, Z be the components of the total magnetic force, X along a meridian, positive North, Y along a parallel, positive West, and Z directed toward the centre of the earth.

Then are X, Y, and Z the partial differential coefficients with respect to x, y, and z respectively of the potential Φ. Gauss has shown in his celebrated memoir how Φ can be expanded in solid, spherical harmonic functions, and found it sufficient to carry the expansion to terms of the fourth order, getting thus 24 coefficients. He has also shown how X, Y, and Z can be expressed in terms of these 24 coefficients ($g_1, g_2, g_3, g_4 \ldots g_{24}$) and of latitude ($\phi$) and longitude ($\lambda$).

Thus,

$$X = f(g_1, g_2, g_3 \ldots g_{24} : \phi, \lambda) = H \cos \delta \quad (1)$$

$$Y = f(g_5, g_6, g_7 \ldots g_{24} : \phi, \lambda) = H \sin \delta \quad (2)$$

$$Z = f(g_1, g_2, g_3 \ldots g_{24} : \phi, \lambda) = H \tan \iota \quad (3)$$

where f_1, f_2, f_3 are functions easily deduced from relation of potential to components of force, as shown by Gauss.

H = horizontal component of force.

δ = declination, and ι = inclination.

As is well known, Gauss obtained his potential expression by selecting points where he possessed observations of 3 elements, H, δ, and ι. So that for each station 3 equations of condition, X, Y, and Z would be obtained containing 24 unknowns, ϕ and λ being of course known. Theoretically, then, 8 stations symmetrically situated, possessing values of H, δ, and ι, would be sufficient. Practically, however, this is not possible, and hence the method of least squares or an equivalent method must be resorted to. The question that confronts us, however, is how we are to obtain X, Y, and Z, and from them Φ, not knowing H. Let us take, for example, epoch 1600.

Here we can easily enough find 24 stations where declinations have been observed. Can we obtain from these data alone an idea of the *distribution* of the force at that epoch?

Divide, *e. g.*, (1) by (2), reduce, and obtain

$$X \sin \delta - Y \cos \delta = 0,$$

or,

$$f_1 (g_1, g_2, g_3 \ldots g_{24} : \phi, \lambda) \sin \delta - f_2 (g_5, g_6, g_7 \ldots g_{24} : \phi, \lambda) \cos \delta = 0. \quad (4)$$

In this equation, as explained before, functions f_1 and f_2 are known, likewise ϕ, λ, and δ; hence (4) is an equation of condition involving nothing more than the 24 Gaussian coefficients. Now as every term of (4) contains one unknown, with the aid of a sufficient number of declinations, all the unknowns can be found with the exception of one. Those determined, then, will be expressed in terms of the undetermined one arbitrarily selected. Hence 28 equations or stations will suffice, if they be approximately symmetrically situated. The conditional equation will be of the following form, if we select g_{24} as the undertermined coefficient: —

$$\frac{g_1}{g_{24}} F_1 + \frac{g_2}{g_{24}} F_2 + \frac{g_3}{g_{24}} F_3 + \ldots . F_{24} = 0, \quad (5)$$

where F_1, F_2, $F_3 \ldots . F_{24}$ are simple known functions of ϕ, λ, and δ. Substituting the values found in (1), the expression of the horizontal component, H, is obtained in terms of the undetermined coefficient g_{24}, or, in other words, *relative* force, not absolute, can be obtained. But this will suffice for the delineation of the prevailing *distribution*. Likewise ϕ can be obtained in terms of the one coefficient.

Furthermore, from (1) and (3) we obtain

$$X \tan \iota - Z \cos \delta = 0,$$

or,

$$f_1 \tan \iota - f_3 \cos \delta = 0. \quad (6)$$

Now, as has been shown, X and Z, or f_1 and f_3, are known terms of one undetermined coefficient, *i. e.*, —

$$X = f_1 = f_1' g_{24}, \text{ and } Z = f_3' g_{24}.$$

Substituting which in (6), we get

$$f_1' \tan \iota - f_3' \cos \delta = 0,$$

or,

$$\tan \iota = \frac{f_3'}{f_1'} \cos \delta = \frac{f_3}{f_1} \cos \delta. \quad (7)$$

Hence the *inclination* can be absolutely determined.

So by means of the above roughly outlined method, the following, among other things, can be found for any epoch where we possess a sufficient number of declinations : —

(1) Distribution of relative force and relative potential.
(2) " " magnetic inclination.
(3) " " " declination.
(4) Localization of Magnetic Poles.

If *both* the declination and inclination are known at a sufficient number of points, equation (6) can be used to determine the coefficients in terms of the undetermined one, and hence an improved [1] expression for relative force and relative potential.

The above investigation has assumed thus far (as did Gauss) that X, Y, and Z can be expressed in terms of the same g's. This, however, is only admissible on Gauss's assumption that the seat of terrestrial magnetic force is wholly nside the earth.

The close agreement of Gauss's computed values with those of observation seemed to indicate that his assumption lies not far from the truth. Later repetitions of the determination of Gaussian coefficients, with far superior material to that possessed by Gauss, have, however, not resulted in material improvement. This seemed to suggest that the Gaussian assumption was not entirely correct, viz., that it was possible that a small part of the observed force may be due to causes coming from outside. In that case, X, Y, and Z could no longer be regarded as functions of one potential, and hence should not be combined in the determination of the coefficients, as the g's would not now be the same. Hence, X, Y, and Z should be treated separately. If the 24 coefficients, as resulting from each set of equations were the same, or differed so little as to be accounted for by observation or computation errors, the Gaussian hypothesis would be correct. If not, then an effect of forces outside, or of currents, say, passing from one region outside to a region within the earth's surface, would have to be taken into account. This test is actually being carried out by Professor Neumayer, of Hamburg, and Doctor Schmid, of Gotha ; and the latter, at the last meeting of the " Deutschen Naturforscher Versammlung," held in Nuremberg, September, '93, stated his belief that his computations had progressed far enough to indicate that such an effect, though a small one, could be taken into account. If this be so, equations (4) and (6) would both have to be considered, or in equation (6) we should have 2×24 coefficients. It might be practicable to proceed thus : —

From an isogonic chart, select points along the igonic lines, *i. e.*, where $\delta = 0$. Then equation (4) reduces to

$$Y = f_2\,(g'_5, g'_6, g'_7 \ldots g'_{24};\ \phi, \lambda) = 0. \qquad (8)$$

From isoclinic chart of same epoch select points along magnetic equator or where $\iota = 0$. Hence (6) simplifies to

$$Z = f_3\,(g''_1, g''_2, g''_3 \ldots g''_{24};\ \phi, \lambda) = 0. \qquad (9)$$

Hence the g's can be determined independently of each other.

[1] Since the coefficients are now determined from two independent sets of observations, viz., declination and inclination.

How practicable the method is can only be determined by trial. It is quite probable that for the purpose at hand the coefficients can be taken as identical. Moreover, by a judicious selection of stations the equations can be simplified, so that the 24 coefficients need not enter in all the conditional equations, and hence the unknowns might be broken up into blocks; *e. g.*, for an intersection of longitudes 0, 180°, 90°, or 270, with the line of zero declination, the equation (8) would contain but six absolute unknowns, or five relative ones. For similar intersections with line of no inclination (magnetic equator[1]), equation (9) would reduce to seven relative unknowns.

The trial can, however, not be made at present for want of force and time. The sole purpose has been to show that *theoretically*, the *solution of the question propounded* above is possible.

STELLAR PHOTOMETRY. By HENRY M. PARKHURST, Brooklyn, N. Y.

[ABSTRACT.]

THE fundamental question is, Shall the photometric scale be fixed by unassisted estimation, or shall photometric apparatus be employed to vary the light of the observed star, as a means of assisting and correcting the estimation? In the former method, having fixed upon a star of the 1^M and another of the 9^M, it is desired to fix the 5^M midway between them. It would be superhuman to hit upon it exactly; and at each subdivision a personal bias necessarily enters. The scale having been fixed by estimation by one astronomer, subject to his personal bias, other astronomers train their judgment to correspond with that scale, however different their own personal bias might be. There would be no means of detecting variation from the strict geometrical ratio; and all must depend upon the original estimation. Increasing the number of observations only tends to confirm and perpetuate whatever inconsistencies there may be.

In photometric methods, personal bias is eliminated; and however crude the observations may be, repetition of the observations tends to remove inconsistencies and to establish strict accuracy. In the experiment which Dr. Mendenhall described to this section a few years ago, he showed that even by "tossing a stick," where each individual trial was far less accurate than unassisted estimation, he obtained a value of π correct to several decimals, his personal bias very slightly affecting the result. Different observers adopting the same method would necessarily have brought out independent results; and the mean of these would have tended to eliminate this slight remaining error. In photometric methods, however crude the individual observations, however subject to accidental errors, accuracy of results is necessarily increased as the number of observations is increased.

Of course it is necessary to avoid systematic error. Whether we compare, as in the Meridian Photometer, or with Zollner's Photometer, observed stars with an unvarying standard, or reduce the light of the observed stars to invisibility, as with my own device, the Deflector, if the circumstances are precisely the same in the successive comparisons, the magnitudes of the compared stars will be

[1] According to one definition

free from error, and personal bias will be eliminated, however erroneous may be the judgment as to what constitutes equality of observed images, or whatever may be the point selected for invisibility.

There are, it is true, various sources of systematic error; but it is our business to discover what they are, and either to remove them or determine the necessary corrections. In the use of the Wedge, and in nearly all methods of reducing the aperture, the sky illumination introduces a systematic error which may become large. That error does not affect observations with the Meridian Photometer, or with my Deflector. It has been cynically remarked of the Harvard observers that their apparatus permitted an endless variety of errors, and they had utilized them all; and perhaps the same may be said of my method; but so long as these are accidental errors only, they will not prevent a gradual approach to accuracy.

In my judgment, the most important source of error in photometric observations, whether with apparatus or by visual comparison, is from the irregularity of the sky. We have a remarkable proof of the existence of this error, affecting whole zones of stars, in Proctor's chart of the Durchmusterung stars, where the zones observed on especially clear evenings stand out boldly from the multiplicity of the stars observable. This is an error more liable to occur in observations of zones of stars, as in the Meridian Photometer Zone Catalogue, a large proportion of the stars in which were observed on two nights only. Closely allied to this zone error arising from the irregularity of the sky, is the zone error arising from erroneous correction for atmospheric obscuration depending upon zenith distance. In my photometric observations in 1869, when I independently discovered the existence and the general law of atmospheric obscuration, I ascertained that it varied on different evenings, sometimes being at least three times the average. In the Harvard observations, the atmospheric obscuration has been assumed to be constant; so that sometimes the correction has been much less than it should be.

A fruitful source of error in observing with the meridian photometer has been the misidentification of stars. I have found many apparent instances of this in the ordinary work of the meridian photometer, where the estimated magnitude of each star was known in advance and used as a guide to assist in identification. Dr. Chandler has suggested, in Astronomische Nachrichten, No. 3214, that in the observation of variable stars, where the brightness of the star was not known in advance, the errors which I attribute to misidentification are so great as to destroy the value of the observations. If he is right in his conclusion, it merely shows that the meridian photometer is not adapted, as it has been used, to the observation of variable stars. My own observations have been purely differential, and the standards have almost exclusively been taken from the immediate neighborhood, in order to avoid the uncertainty of atmospheric obscuration. Consequently my magnitudes are largely affected by the same local causes which have affected the standards. On the other hand, my method is almost entirely free from danger of misidentification, each star being fully identified at the time of observation by the configuration of the group.

Since the completion of my Catalogue of Comparison Stars (H. C. O. Annals, Vol. xxix.) I have started anew, cutting myself aloof from all the errors of

individual stars in the Meridian Photometer catalogues, and in my earlier observations. These later observations include about a thousand stars, a few of them observed more than fifty times each, contained in more than a hundred groups. Comparing my own results with each other, and comparing the meridian photometer observations with each other, produce nearly the same mean difference; but the difference is nearly twice as great in comparing the meridian photometer observations with my own. This difference I attribute to two causes: first, the change of my values in certain localities from equalizing the obscuration corrections employed in the Harvard catalogues; and second, a change in the stars themselves. In about four per cent of the stars, which I denominate fluctuating, this variation may amount to half a magnitude or more. It will require further observation and investigation to determine the changes of the other stars. It is enough for my present purpose if I have shown from independent observation that the criticisms of Dr. Chandler are not applicable to the main body of the observations with the meridian photometer, but chiefly relate to the attempt to use it in the observation of variable stars, for which it is not adapted.

[Details were given respecting the comparisons upon which the foregoing conclusion was founded.]

A SIMPLE PROOF OF RADAU'S SYMMETRICAL FORM OF THE DIFFERENTIAL EQUATIONS OF RELATIVE MOTION OF THE PLANETS. By Prof. ORMOND STONE, University of Virginia, Charlottesville, Va.

[ABSTRACT.]

1. Proof of relation between co-ordinates.
2. " " Equations of Energy.
3. " " " " Area.
4. Deriviation of final Forms.

[Paper to be printed in Annals of Mathematics.]

RECENT LATITUDE DETERMINATION AT THE SAYRE OBSERVATORY, BETHLEHEM, PENNSYLVANIA. By Prof. C. L. DOOLITTLE, Bethlehem, Pa.

[ABSTRACT.]

THIS is a continuation of the latitude work which has been in progress at Bethlehem for a number of years.

ON THE CONTROL OF THE EQUATORIAL DRIVING CLOCK. By Prof. G. W. HOUGH. Northwestern Univ., Evanston, Ill.

[ABSTRACT.]

THE paper consisted of a discussion of methods for securing uniform rate.

ON SOME ATTEMPTS TO PHOTOGRAPH THE SOLAR CORONA WITHOUT AN ECLIPSE. By Prof. GEORGE E. HALE, Kenwood Observatory, Chicago, Ill.

[ABSTRACT.]

THE paper was a discussion of various methods for photographing the solar corona without an eclipse.

[This paper will be printed in Astronomy and Astro-Physics.]

REQUISITES FOR GOVERNING THE MOTION OF EQUATORIAL TELESCOPES. By W. R. WARNER, Cleveland, Ohio.

GILLISS' CATALOGUE OF SOUTHERN STARS. By Prof. EDGAR FRISBY, U. S. Naval Observatory, Washington, D. C.

SKETCH OF ZONE OBSERVATIONS AT THE NAVAL OBSERVATORY. By AARON N. SKINNER, U. S. Naval Observatory, Washington, D.C.

PRELIMINARY NOTICE OF RESULTS OF OBSERVATIONS MADE AT COLUMBIA COLLEGE OBSERVATORY FOR VARIATION IN LATITUDE AND CONSTANT OF ABERRATION. By Prof. J. K. REES, Columbia College, New York, N. Y.

A CONFIGURATION OF 36 POINTS, 27 LINES, 36 PLANES, A SPECIAL CASE OF WHICH LEADS TO KLEIN'S HYPERELLIPTIC CONFIGURATION OF 40 POINTS, 90 LINES, 40 PLANES. By Professor E. HASTINGS MOORE, The University of Chicago.

[ABSTRACT.]

THE configuration is determined by an arbitrary fundamental tetraedron, and an arbitrary transversal (not lying in a face or passing through a vertex of the tetraedron). These elements determine a Reye's tetraedral complex, whose lines $\left\{\begin{array}{l}\text{cut the faces}\\ \text{are joined to the vertices}\end{array}\right\}$ of the tetraedron in $\left\{\begin{array}{l}\text{ranges}\\ \text{axial pencils}\end{array}\right\}$ of four $\left\{\begin{array}{l}\text{points}\\ \text{planes}\end{array}\right\}$ having the same anharmonic ratio. The 27 Cf-lines belong to this complex, the transversal being a Cf-line. The 36 $\left\{\begin{array}{l}\text{Cf-points lie}\\ \text{Cf-planes pass}\end{array}\right\}$ by fours $\left\{\begin{array}{l}\text{on}\\ \text{through}\end{array}\right\}$ the 27 Cf-lines, and by nines $\left\{\begin{array}{l}\text{on the 4 faces}\\ \text{through the 4 vertices}\end{array}\right\}$ of the fundamental tetraedron.

If in particular the transversal cuts the four faces in a range of four points which is *equianharmonic*, then by adjoining certain elements to our configuration we obtain Klein's hyperelliptic configuration[1] of 40 points, 90 lines, 40 planes.

[To be printed in full in Amer. Jour. Math.]

[1] Witting: Ueber eine der Hesse'schen Configuration der ebenen Curve dritter Ordnung analoge Configuration im Raume auf welche die Transformationstheorie der hyperelliptischen Functionen ($p = 2$) führt: Inaugural-dissertation, Dresden, 1887.

Maschke: Aufstellung des vollen Formensystems einer quaternären Gruppe von 51840 linearen Substitutionen: Mathematische Annalen, vol. 33, pp. 317-344, 1888.

SECTION B.

PHYSICS.

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ADDRESS

BY

WILLIAM A. ROGERS,

VICE PRESIDENT, SECTION B.

OBSCURE HEAT AS AN AGENT IN PRODUCING EXPANSION IN METALS, UNDER AIR CONTACT.

THE qualifying clause "under air contact," in the title of the subject to which I ask your attention, in the address which I am called upon to make as presiding officer of this Section, has been advisedly chosen.

Whatever may be said of the advantages offered, either by liquid contacts of the metals investigated, or by freedom from exposure to the air in the comparison of standards of length, the fact remains that a useful purpose will be served by a study of the forces under which the expansion and contraction of metals take place, *under the conditions in which they are used in every-day experience.*

It is not my intention to enter upon a prolonged discussion of the relative advantages of liquid and of air contacts, but it may be worth while at this time to mention the precautions which must be taken when the two metals employed are either wholly or partly immersed in water.

First. Water, except at a very low temperature, never rises to the temperature of the air to which its surface is exposed. The cooling effect of the evaporation which takes place increases with the temperature, and the extent to which the water is cooled depends upon the mass of the liquid exposed and especially upon its depth. I give in this connection the results of a series of observations which substantiate the law thus stated. Galvanized iron pans

about eighteen inches in length, from four to six inches in width, and from four to eight inches in depth, were placed upon separate supports in the equal temperature room of the Shannon Physical Laboratory. In these pans was placed water varying in depth between one-half inch and eight inches. One thermometer was suspended horizontally upon wires a little below the surface of the water, and another, upon similar supports, was placed about one-quarter inch above the surface of the water. The results given in the following table were obtained from readings of each set of thermometers under a nearly constant temperature extending over periods of from four to five days for each condition of temperature investigated.

TABLE I.

TEMPERATURE OF WATER BELOW THAT OF THE AIR.

		DEPTH OF WATER.			
	τ Fahr.	1 in.	1 in.	4 in.	6-8 in.
	55°	0.58°	0.42°	0.22°	0.18°
	56	.59	.44	.27	.25
	57	.64	.43	.34	.40
	58	.78	.53	.44	.33
	59	.88	.57	.33	.29
	61	.93	.66	.36	.22
	62	.82	.54	.28	.24
	63	.73	.51	.29	.28
	64	.83	.53	.25	.18
	65	.89	.58	.22	.15
Means	60.0	0.77	0.52	0.30	0.25

The following table will indicate the range of deviation between the individual comparisons:

Date.	τ.	Depth = ½ in. Water lower than the air.	Date.	τ.	Depth = ½ in. Water lower than the air.
1890, Sept. 17	64°	+0.74°	1890, July 17	79°	+1.71°
18	63	.72	18	78	1.73
20	62	.93	20	80	1.86
22	62	.82	21	89	2.02
22	61	.50	22	79	1.31
			23	77	1.99
Means	62.4	0.74	24	76	1.85
			Means	79.8	1.78

SERIES OF OBSERVATIONS MADE IN 1894.

	For a vessel 50 x 5 x 5 inches filled with water.		For a vessel 44 x 1¼ x 4 inches filled with water.	
	70.7°	+0.83°	69.6°	+0.47°
	71.9	0.81	72.3	.55
	72.6	0.80	73.4	.40
Means	71.7	0.81	71.8	0.47

Second. Aside from the cooling effect of evaporation, there is another disturbing cause. The time required for a metal under water contact to pass from complete saturation at a constant temperature to complete saturation at another temperature, also constant, is *some* function of the conductivities and of the thermal capacities of the two substances. For bars of steel and of brass, having a cross-section of one square inch, under air contact, this time does not vary much from four hours, but for water under similar conditions of exposure the time is not far from seventeen hours. When, therefore, the metals are exposed to water contact under the conditions defined above, changes of condition will take place under the action of two constantly varying thermal forces.

Third. The walls of the containing vessel will, in every case, be found to have a higher temperature than that of the liquid. A bar of metal, partially submerged in water, will have a constant higher temperature than that of the water,—the amount depending on the extent of the surface exposed to the air. In the case of a bar having a cross section of one square inch and having its upper surface elevated ⅛ of an inch above the surface of the water, this constant was found to be 0°.15 Fahr.

Finally, the uncertainty in the determination of the temperature in the observations, from which Table I was constructed, was found to be far greater for large than for small depths.

The results here stated have been verified by observations made with the radiometer, invented by Professor Hutchins of Bowdoin College. This instrument consists of a junction of bismuth and antimony, about one five-hundredth of an inch in thickness, placed in the focus of a silvered concave mirror. With a mirror galvanometer, having a resistance of about ¼ of an ohm, this instrument has been found to be very serviceable in exploring the surface temperatures of the walls of the comparing rooms and of different

parts of the comparator. In one series of experiments, a block of lead was placed in water, with its exposed surface as nearly as possible in the same plane as the surface of the water. After the vessel had remained at a nearly constant temperature of 80° for several days, the radiometer was held for a moment, first over the water and then over the lead. A difference of temperature, amounting to about 2°, was instantly made apparent from the change of readings on the galvanometer scale.

Very early in my experience in comparing standards of length, an apparently abnormal thermal condition was forced upon my attention by the persistence with which it occurred. It was found in the comparison of a steel with a bronze standard that, when a rise of temperature occurred, the value of the difference in length obtained by reducing the observed relation to *e. g.* 62° Fahr., with the known relative coëfficient of expansion and with temperatures taken from the readings of thermometers placed upon the surfaces of the bars, differed from the true relation by a quantity which very soon became constant and remained so as long as the temperature continued to rise. For falling temperatures it was found that this constant had the opposite sign and a slightly smaller value. The value of this constant was found to vary between 0.5μ for very slow changes in temperature and 5.0μ for rapid changes. Moreover it was found that a different constant having an opposite sign, was obtained when the reductions were made with temperatures taken from the readings of thermometers placed in slots in the bars extending in depth to the center of the bars and from which the air was, as nearly as possible, excluded.

Without at first attempting to formulate a theory by which these apparent anomalies could be explained, it was soon found that practically the true relation between the two standards could be obtained in two ways: first, by combining the results obtained under a rising with those obtained under a falling temperature; and, secondly, by employing the mean of the readings of the thermometer placed upon the surface of the bar and of the one placed in the slot in making the reductions to 62°.

It was also soon found that these combinations could be made between results obtained at different times, and without much regard to the actual temperatures at which a rise or fall commenced. Thus a rise from 0° to 10° could be combined with a fall from 90° to 80°, provided the *rate* of change was nearly the same. It was

found that, for the most part, the results from a rising temperature demanded a slightly larger correction than those from a falling temperature, especially when the change in temperature was rapid.

It was also found that the elimination of errors could be made with much greater certainty in contiguous comparisons under steady increments and decrements of temperature, even when the rate of change was quite rapid; and that the danger of failure in making the proper elimination was by far the greatest for an apparently constant temperature.

Finally, it very soon became evident that the observed deviations were in some way connected with the previous thermal condition of the bars compared, of the thermometer, of the bed of the comparator, and of the walls of the comparing room.

Before commencing a discussion of the questions involved in this statement of actual experience, it will be well at this point to describe the appliances by the aid of which the observations upon which this discussion will rest, have been made.

The form of the comparing instruments employed is shown in Figs. 1 and 2. The form in Fig. 1 has a capacity of fifty inches; that shown in Fig. 2 has a capacity of one hundred inches. Inasmuch as both of these instruments have been described elsewhere it will not be necessary to enter upon a detailed description here. It will be seen that either of the bars compared can be quickly brought into position under the microscope without contact with the hands of the observer. The stop method, fully described elsewhere, has been almost exclusively used. Since each bar is brought in succession under the same microscope, danger of error through a curvature of the ways is avoided. The ways of the comparator were made straight by a slow process of correction, and in their present condition it may be said that for a distance of forty-eight inches the radius of curvature cannot be much less than 500 miles.

The method of comparing a line measure with an end measure in melting ice will need a brief description. The ice box marked (16) has in it a round steel rod one inch in diameter, which is supported permanently at the two conical projections at the ends. The projecting ends, one of which is oval and the other flat, were made as hard as possible. The entire bar, except about $\frac{1}{16}$ inch at each end, is surrounded with the melting ice with which the box is filled. When in position upon the comparator, the box rests upon the plates placed upon the ways. To each is clamped an L

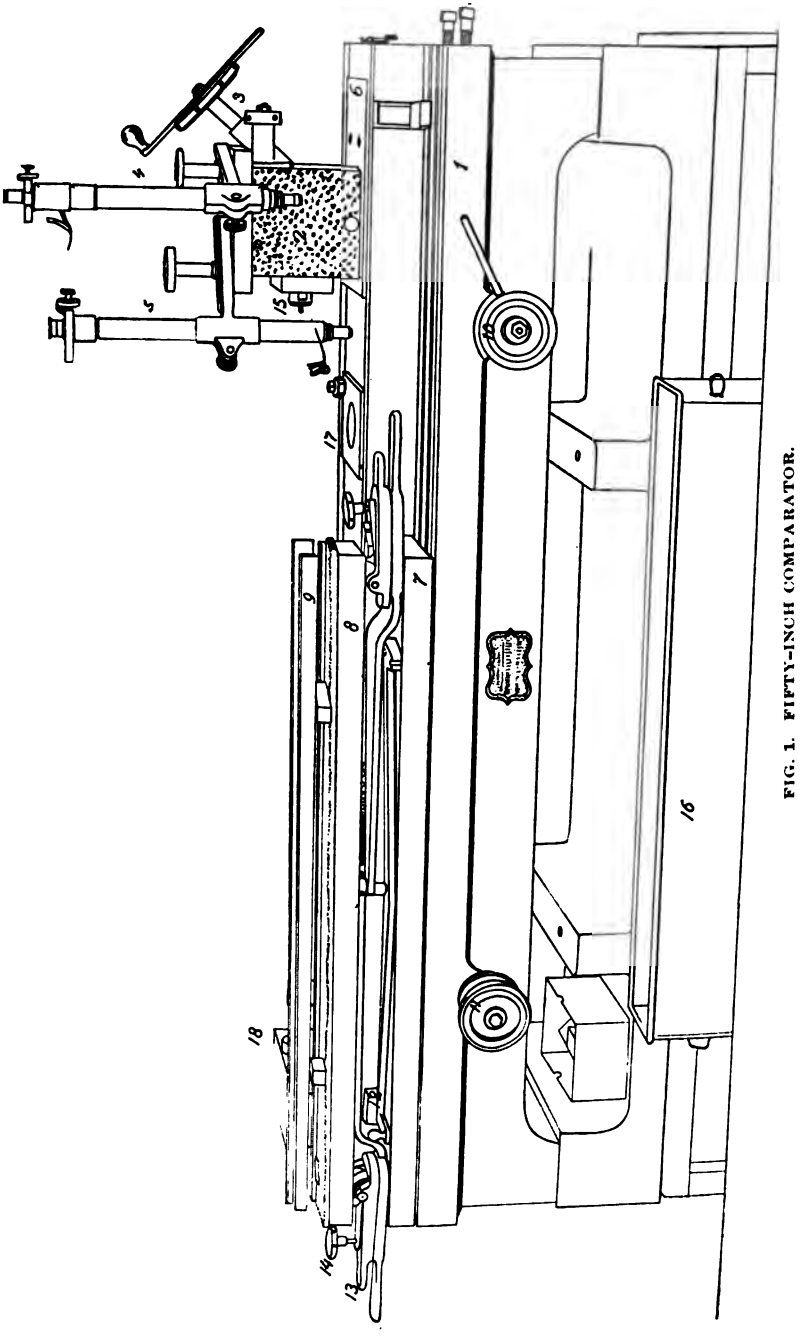

FIG. 1. FIFTY-INCH COMPARATOR.

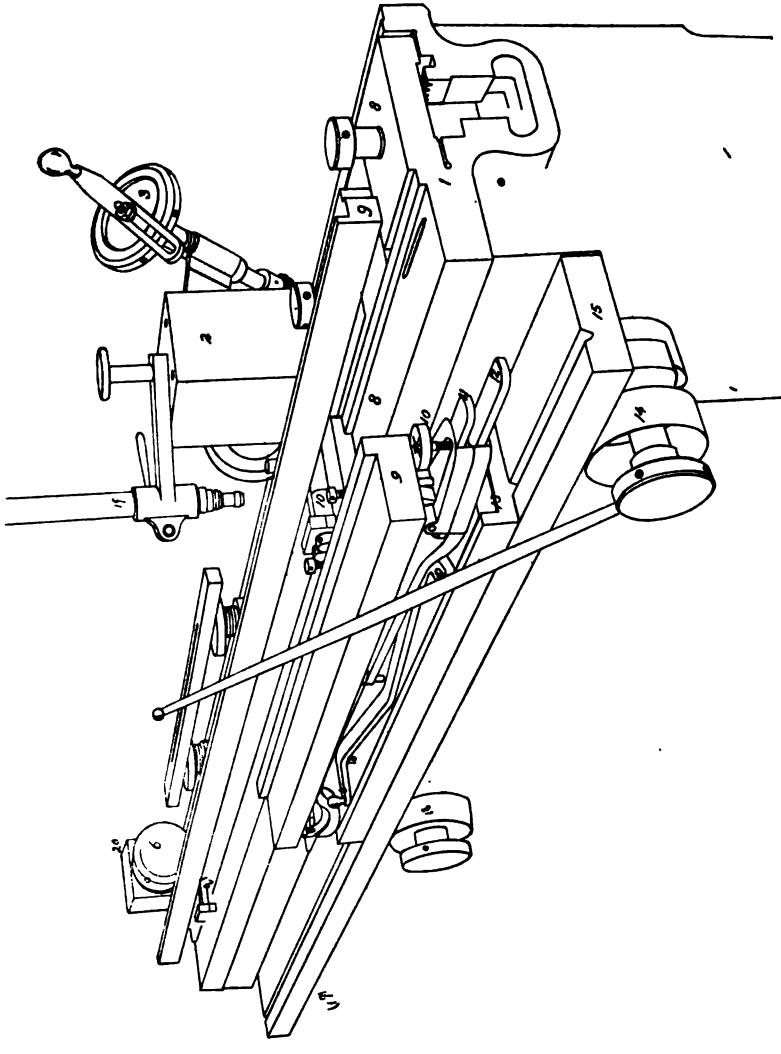

FIG. 2. ONE-HUNDRED-INCH COMPARATOR.

shaped stop shown at (17) by means of which the box can be brought into a constant position. The stop on the microscope carriage is seen at (15). A corresponding one is attached to the fixed plate (18). The operation of making the comparison is described as follows: (1) The microscope carriage is brought into contact with the fixed stop at (18). The line bar is then brought under the microscope and adjusted parallel with the ways of the comparator and for sharp focus on the defining lines of the bar. (2) The micrometer having been read for coincidence with the initial line, the carriage is moved to the other end of the ways. (3) The supporting plates for the ice box are placed in position and the ice box is adjusted upon them and brought into contact with the left-hand stop. (4) The carriage is now brought into contact with the other end of the ice box and a second reading of the micrometer is taken for coincidence with the terminal line of the bar compared. (5) The ice box is then removed, contact is made with the left stop, and another reading is taken for coincidence with the initial line.

Two instruments of the form shown in Fig. 1 are in use, a new one having been set up in 1887. Previous to March, 1890, the comparator was mounted in the room adjoining my lecture-room in the third story of Recitation Hall. The lecture-room is 25x20x11 feet and has windows on the south and the west sides. The comparing room is 25x15x11 feet. It has one large window at the south end and two on the east side. Communication between the two rooms is by means of a single door at one corner of the room and also by four adjustable shutters in the upper part of the partition between the two rooms. As will appear later, a most important and interesting series of comparisons was made in this room, extending from Oct. 28, 1888, to Feb. 16, 1889, to which attention will be presently called. By opening all the windows, shutters and doors, it was found possible to approximate to the conditions of open air exposure. In February, 1889, a complete series of comparisons were obtained at —13° Fahr. The comparator was removed to the equal temperature room of the Shannon Physical Laboratory March 24, 1890. This comparing room has the dimensions 58x 30x16 feet. The outer walls of the building are eighteen inches in thickness. An inner wall with two-inch air space, twelve inches in thickness, forms the outer boundary of the room. Between these walls there is on every side a clear space of eighteen inches. There

is a space of three feet between the ceiling and the floor of the lecture-room in the second story, and there is a cellar with a clear height of seven feet under the whole building. At the central part of the large room there is an inner room with double walls and asbestos partitions, having the dimensions 14x9x16 feet. The observations to be described were made in this room.

The large comparing room is heated by two methods: (1) by an overhead steam pipe circulation extending entirely around the room; and (2) by means of hot air delivered by means of ten-inch pipes to the air space surrounding the room, by a blower of two-horse power capacity, by what is known as the Sturtevant system of heating. By this system, both the cellar, the spaces between the walls and the space between the two upper floors can be heated either unitedly or separately. There is an underground passage from the heat storage room to the open air and to an ice reservoir. Either hot or cold air can, therefore, be delivered to any part of the building. There is also a pipe connecting with the space between the walls of the inner room, by which either hot or cold air or steam can be delivered in any quantity desired, in order to obtain any desired temperature in the inner room and to hold it until the completion of any desired experiment under a given constant condition of temperature. It is found perfectly feasible to maintain indefinitely in the inner comparing room a constant temperature within a few hundredths of a degree. Finally, wires from a large storage battery deliver a sufficient current for maintaining liquids at a constant temperature.

In the discussion of the points at issue, it will be obvious that all doubts which relate to the auxiliary instruments employed and to the method of observations adopted should be, as far as possible, removed.

(*a*) Can the observations for temperature be depended upon as far as they relate to the normal indications of the thermometers?

In answer to this inquiry it will be sufficient to offer the data in the following table. Column (1) contains the correction to Tonnelot 62, as determined by my own comparisons with Green 1503, loaned to me by the U. S. Signal Office, and by subsequent comparisons with Green 2294, whose corrections were determined with great care by Professor C. F. Marvin of the Signal Office.

The corrections given in Table II were determined independently, as indicated in the headings of the different columns. The

Coast Survey comparisons were made with the Standard of the International Bureau. The official corrections of the Signal Office Standards depend upon the thermal relations established by Mr. Thomas Russell.

TABLE II.

	(1)	(2)	(3)	(4)
τ	Rogers	Coast Survey.	Signal Office. 1891.	Signal Office. 1893.
°	°	°	°	°
0	—0.43	—0.36	—0.40	—0.40
5	—0.48	—0.45	—0.49	—0.51
10	—0.51	—0.45	—0.50	—0.56
16	—0.56	—0.52	—0.53	—0.60
21	—0.58	—0.53	—0.58	—0.65
25	—0.58	—0.57	—0.60	—0.65
27	—0.58	. . . .	—0.58	—0.63
31	—0.59	—0.61	—0.61	—0.68

(*b*) Is it possible to determine the true value of the relations between the standards of length by a method of observation, which will secure freedom from the errors whose elimination is sought?

It may be said in answer to this inquiry, that the writer has made yearly comparisons between his bronze standard and steel standard since 1881, and in no case has the result for any year differed as much as 0.5 μ from the mean value adopted. It will appear from the data which will be given later, that there can be no reasonable doubt but that the true relation between the standards compared, has been obtained within $\pm$ 0.2 μ.

(*c*) Are the deviations described real? And can they be traced to the obscure radiations between the bars compared and large masses of matter in a more or less close proximity to the bars?

The answer to these inquiries will constitute the principal subject of this address.

Attention is called at this point to the result of a series of comparisons made in 1884 between standards R_2 and R_3. The standards were placed side by side in a comparing room fitted up in the basement of the rotunda of the observatory of Harvard College. The comparator was situated about ten feet from the immense stone pier which supports the great equatorial of the observatory.

TABLE III.

	LIMITING DATES.		R_2-R_3
1886	May 25, . . .	May 27,	5.32μ
	May 28, . . .	June 2,	4.48
	June 3, . . .	June 16,	4.02
	June 17, . . .	June 27,	2.23
	June 28, . . .	July 8,	2.34

It will be seen that we have here an instance of a slow diminution of the observed relation probably caused by the greater effect of the inter-radiations between the pier and the bar nearest to it and that between the pier and the bar one inch farther away.

In order to determine the effect of the interchange of radiations between the bed of the comparator on one hand, and a large mass of stone on the other, with the bars between the two masses, a comparator was mounted in the open air on the west side of Coburn Hall, one of the college buildings. The comparator was placed about two feet from the wall of the building. The following results were obtained :—

TABLE IV.

R_2 between the body of the comparator and the wall of the building.			R_3 between the body of the comparator and the wall of the building.			
Date.	τ	R_2-R_3	Date.	τ	R_2-R_3	Means.
	°			°		
1888, July 4,	45.2	—3.3μ	June 1,	57.2	+1.5μ	—0.9μ
" 4,	50.0	—2.8	" 1,	58.3	+0.8	—1.0
" 4,	53.6	—2.5	" 3,	60.7	+0.4	—1.0
" 5,	40.5	—1.5	" 3,	63.2	+0.6	—0.5
" 5,	47.9	—3.2	" 13,	55 8	+2.5	—0.4
" 5,	50.2	—4.7	" 13,	57.0	+2.1	—1.3
	Means	—3.0			+1.6	—0.7

We see, therefore, that when the bronze bar R_2 was nearer the building than the steel bar R_3, the steel bar was found to be 3.0 mikrons longer than the bronze bar; but that when R_3 was nearer the building than R_2, the steel bar was found to be 1.6 mikrons shorter than the bronze bar, but the mean of these two values differs only 0.2 mikron from the real relation as determined by comparisons extending over a period of several years.

The general statement of the problem given on page 68 is pretty fully illustrated by the following examples: They are given for the purpose of showing the necessity of recognizing the thermal forces which produce the changes observed, and, at the

same time, of pointing out in an extreme case, the manner in which the errors involved may be eliminated. The bars compared have longitudinal slots, extending to their centers, for receiving one set of thermometers. The readings of the bronze bar B, which has the thermometer in the slot, are designated B_1, and the one which has the thermometer placed upon the surface of the bar is designated B_2. Similarly the readings for the steel bar are designated S_1 and S_2. Previous to the observations of Nov. 8 and Nov. 11, the fire in a wood stove had been banked during the preceding night. The observations for Dec. 18 were made under similar conditions in regard to the banked fire during the previous night, but the fire was renewed early in the morning. In the observations of Dec. 25, the windows of the comparing room were left open during the night, but were closed early in the morning.

TABLE V.

COMPARISONS UNDER A RISING TEMPERATURE.

Date	τ	B τ_1	B τ_2	S τ_3	S τ_4	B—S Reduced to 62°.0 Fahr. with τ_1	τ_2	τ_3	τ_4	Means of (1) and (2).	Means of (3) and (4).
	Bar B, front.										
	h. m.										
1888, Dec. 18	2 10	92.62	91.83	92.84	92.86	+ 7.2 μ	+ 7.6 μ	+ 6.0 μ	+ 4.2 μ		
	2 35	93.18	93.60	93.30	94.52	+ 7.2	+ 5.6	+ 6.4	+ 2.6		
	3 20	95.01	95.77	95.00	97.40	+ 7.0	+ 2.8	+ 6.4	− 0.8		
	4 40	99.97	99.99	99.90	101.01	+ 4.4	+ 3.0	+ 4.2	− 0.6		
						+ 6.5	+ 4.8	+ 5.8	+ 1.3	+ 5.6 μ	+ 3.5 μ
	Bar B, rear.										
Dec. 23	9 40	13.64	15.50	13.94	14.60	+10.4	+ 5.2	+11.2	+ 9.0		
	12 55	16.46	17.61	16.73	17.30	+11.4	+ 5.6	+10.1	+ 9.6		
	3 12	18.14	19.24	18.40	18.90	+11.4	+ 7.0	+ 9.2	+ 9.6		
	6 45	19.62	20.71	19.85	19.70	+11.4	+ 5.9	+ 8.6	+ 8.6		
						+11.2	+ 5.9	+ 9.8	+ 9.2	+ 8.5	+ 9.5
									Means	+ 7.0	+ 6.5

COMPARISONS UNDER A FALLING TEMPERATURE.

	Bar B, rear.										
Nov. 9	8 00	73.83	71.82	75.09	73.94	− 2.0	+ 6.2	− 5.8	− 1.0		
	12 25	68.14	67.57	68.76	68.62	+ 3.0	+ 4.2	+ 1.8	+ 2.0		
	3 10	66.49	65.69	66.70	65.79	+ 5.6	+ 8.4	+ 5.0	+ 4.6		
						+ 2.2	+ 6.3	+ 0.3	+ 1.9	+ 4.2	+ 1.1
	Bar B, front.										
Nov. 11	7 05	73.62	71.75	72.46	70.39	+11.0	+17.4	+15.4	+23.4		
	9 30	68.18	67.45	68.07	66.54	+ 9.0	+14.1	+11.8	+18.8		
	11 30	65.43	64.46	65.21	64.08	+10.0	+13.8	+11.0	+15.2		
	2 20	61.78	60.81	61.51	60.36	+ 9.2	+13.2	+10.2	+14.4		
						+ 9.8	+14.6	+12.1	+17.9	+12.2	+15.0
									Means	+ 8.2	+ 8.0

For the final mean we have, $\frac{1}{2}\left[\frac{7.0+5.6}{2}+\frac{8.2+8.0}{2}\right]=7.4\ \mu$.

The mean of 1200 comparisons gave the value, $6.8\ \mu$.

By taking into account the results for opposite conditions of temperature, with the relative positions of the bars unchanged, we have:

TABLE VI.

B FOR A RISING TEMPERATURE.					B FOR A FALLING TEMPERATURE.				
Rear	+11.2 μ	+5.9 μ	+9.8 μ	+9.2 μ	Front	+6.5 μ	+4.8 μ	+5.8 μ	+1.3 μ
Rear	+ 2.2	+6.3	+0.2	+1.9	Front	+9.8	+14.6	+12.1	+17.8
Means	+ 6.7	+6.1	+5.0	+5.5		+8.1	+ 9.7	+ 8.9	+ 9.5
		+6.3		+5.2			+8.9		+9.2

The final mean $=\frac{1}{2}\left[\frac{6.3+5.2}{2}+\frac{8.9+9.2}{2}\right]=7.4\ \mu$.

(*d*) Can a mercurial thermometer be relied upon to give the true temperature of the bars to be compared?

Before attempting an answer to this inquiry, it may be well to present a provisional account of the thermal forces under which the length of a bar of metal is changed.

(*a*) Supposing that the thermometer rests horizontally upon the upper surface of a bar of metal, but with its bulb in contact with it, the position of the mercurial column will depend upon the action of the following forces:—

First, upon the transfer of heat between the bulb and the mass of the metal with which it is in contact, by conduction; *second*, upon the temperature of the air which forms an envelope about the portion of the bulb which is not in contact with the metal; *third*, upon the time required for both metals to pass from complete saturation at any constant temperature, to complete saturation at any other temperature also constant, *under the condition in which an actual change of temperature takes place;* and *fourth*, upon the previous thermal condition both of the bar of metal and of the thermometer. Meanwhile both the bars and the thermometers are affected by the obscure radiations from neighboring masses of matter, having a temperature different from that of the smaller masses. The surfaces of the bars and also of the thermometer are bombarded by the blows delivered by heat-waves, somewhat in proportion to the extent of the surfaces exposed, on the supposition that they have the same absorbing power.

Let us take a concrete case. I stand in close proximity to the thermometers which rest upon the surfaces of the bars to be com-

pared. The layer of air nearest to my body is heated by conduction, regarding air as matter having a very small mass. The adjacent layers being heated by convection, a rise of temperature of the air takes place which surrounds the exposed portions of the bulb of the thermometer. The visible effect will be a rise in the column of mercury, unless it is held in check by the counter-action of the metal in contact with the bulb. The indicated height of the column is the resultant mainly of these two forces under the equilibrium which is very soon established. But other forces are acting at the same time. The rate of the change in the temperature of the glass, and of the different masses of metal, undergoes continual variation, on account of the different coëfficients of conductivity which the different substances have. Moreover, the rate of change is slower for bodies having the larger mass.

At the same time also there is an interchange of radiations between the thermometer, the bars, the person of the observer, and neighboring large masses of matter, which is nearly proportional to the extent of surface exposed and hence producing only a trifling effect upon the thermometer. The study of these interchanges of radiations forms the subject of this investigation.

I assume that it is not yet possible to make an actual separation of the thermal forces manifested in the transfer of heat by conduction, by convection, and by radiation, but I have endeavored to determine differentially the work done by radiations from neighboring large masses of matter, in producing changes in the dimensions of metals. May I be permitted to suggest that until the actual thermal effects of conduction, convection and radiation can be separated and measured, the designations themselves have but little scientific value except as a general statement of different conditions. Maxwell's statement that all heat is of the same kind may be true in the sense that every manifestation of heat produces molecular agitation, but how can we assert, with our present knowledge of the subject, that the *degree* of agitation in the case of conduction is at all comparable with that which takes place through radiation, in which the energy is conveyed through intervening spaces by harmonic wave motions.

I have said that the time required to pass from one constant thermal condition to another is *some* function both of the conductivity and of the thermal capacity of the substances heated or cooled. The time required for a thermometer to pass from one

constant temperature to another, under air contact, varies in different thermometers from about twenty to twenty-seven minutes. The time required for bars of brass and of steel having a cross section of one square inch is in the neighborhood of four hours. It is obvious that when the thermometers are in contact with the metal, a different law of cooling must prevail from that which holds when their change of thermal condition is considered independently.

The application of Newton's law of cooling ought to enable us to determine whether the same law holds under the two conditions of separation and of contact. It ought also to furnish the data for determining whether the same law prevails when equilibrium is nearly reached as that which holds during more rapid changes. Let us first apply this law to the indications of a thermometer under both rising and falling temperatures.

Let a = the constant temperature of the air to which the thermometer is removed after complete saturation at a different temperature.

b = the readings of the thermometer at equidistant intervals of the time T after removal to condition (a).

τ = equal intervals of T.

$\mu = b - a$.

μ_0 = the initial value of μ.

e = the Naperian base.

c = a constant.

Then, by Newton's law:

$$\mu = \mu_0 e^{-c\tau}.$$

Whence:

$$\log c = \log [\log \mu_0 - \log \mu] - [\log \tau + 9.6378],$$

$$\log \tau = \log [\log \mu_0 - \log \mu] - [\log c + 9.6378],$$

$$\log \mu = \log \mu_0 + [10 - \text{no. corresponding to } [\log \tau + \log c + 9.6378]].$$

The reduction for a portion of a single experiment will be given in detail by way of illustration.

Feb. 19, 1889, $8^h\ 0^m$; removed Green 1503 from 64°.3 to comparing room at 36°.20.

T	τ	(b)	(a)	μ	$\log \mu$	$[\log \mu_o - \log \mu]$
		°	°	°		
8h 2m	0s	50.07	36.20	13.87	1.1421	
4	120	44.04		7.84	0 8943	0.2478
6	240	40.72		4.52	0.6551	0.4870
8	360	39.04		2.84	0.4533	0.6888
10	480	37.95		1.75	0.2430	0.8991
12	600	39.29	36.20	1.09	0.0374	1.1047

$\log [\log \mu_o - \log \mu]$	$[\log \tau + 9.6378]$	$\log c$	c
9.3941	1.7170	7.6770	.0047
9.6875	2.0180	7.6695	.0047
9.8375	2.1941	7.6434	.0044
9.9538	2.3190	7.6348	.0048
0 0432	2.4160	7.6272	.0042
		Mea	.00446

In order to ascertain whether the computed values of c, for an entire series of comparisons, remain constant, the following résumé of the results of different experiments is given:—

FOR THERMOMETER 1503.

Date.	Range of temperature.	τ	Limits of μ.	c.
	° °		° °	
1889, Feb. 20.	53.0 to 32.40	21m	12.10 . . . 0 05	.00436
Feb. 22.	7.0 " 11.64	26	2.55 . . . 0.02	.00403
Feb. 23.	92.3 " 11.44	26	40.21 . . . 0.05	.00447
Feb. 26.	22.4 " 66.35	24	17.67 . . . 0.00	.00425
Feb. 27.	107.4 " 32.07	25	36.91 . . . 0.02	.00417
Feb. 28.	86.0 " 33.74	21	27.40 . . . 0.01	.00425
Mar. 9.	103.0 " 29.04	27	43.85 . . . 0.08	.00459
Mar. 9.	90 7 " 29.48	24	40.50 . . . 0.01	.00415
Mar. 9.	39.2 " 61.30	21	4.68 . . . 0.09	.00400
			Mean	.00425

FOR THERMOMETER 2292.

Date.	Range of temperature.	τ	Limits of μ.	c.
	° °		° °	
Feb. 20.	88.4 to 11.38	28m	33.40 . . . 0.01	.00492
Feb. 21.	7.0 " 68.60	26	37.95 . . . 0.09	.00492
Mar. 9.	90.7 " 29.50	23	28.71 . . . 0.01	.00495
			Mean	.00493

It therefore appears that Newton's law very nearly represents the law of cooling for a thermometer suspended in air. It will be seen that under widely varying conditions the value of c remains practically constant. Slightly smaller values of c will be obtained by taking the initial instant with a less interval between the time of removal and the time of the first comparison. It will be found better to allow an interval of four or five minutes to elapse before the initial instant is chosen. With this exception there does not seem to be any variation in the value of c until the point of equilibrium is nearly reached; after which the values become very slightly smaller. It will also be noticed that the time required to pass from one constant thermal condition to another under air contact is nearly constant.

It was from a discussion similar to the above, relating both to thermometers and to bars of metal, that the two following laws were formulated in 1887. I have since seen no reason to doubt their substantial truth. These laws are stated as follows (see Proceedings of American Microscopical Society for 1887, pp. 65–66):

(1) Under air contact, the time required for thermometers, and for bars of steel and bronze to pass from complete saturation at a constant temperature to complete saturation at another temperature also constant, is nearly a constant.

(2) Under air contact, the time required to pass from complete saturation at any observed constant temperature to complete saturation at any other constant temperature is nearly independent of the range between the initial and the final temperatures. Thus the time from 0° to 5° is nearly the same as the time from 0° to 125°.

Thus far we have considered the thermometer as suspended alone in air in which case Newton's law holds. But in a more complicated system in which different thermal capacities, conductivities and emissive and absorptive powers enter, Newton's law may not hold true. Take, for instance, a system which is made up of glass jars containing mercury or water, in which a thermometer is suspended vertically. In this case, as will be seen, Newton's law is only approximately true.

Equal volumes of mercury and water, in which thermometers were suspended in a vertical position, were removed from complete saturation at different temperatures, to the inner comparing room in which a constant temperature was maintained. The readings

of the thermometers were then made from the outside through a plate-glass window. The following data were obtained from a single experiment. Only the values of μ are given.

July 10, 1894, $10^h\ 6^m$; removed separate vessels of mercury and of water from 35.°0 to the comparing room at 68°.08.

Time.	For mercury. μ	For water. μ	Δ
	°	°	
$10^h\ 10^m$	26.95	27.72	+0.77
10 20	13.80	18.32	+4.52
10 30	8.87	13.02	+4.15
10 40	6.60	9 68	+3.08
10 50	5.06	7.41	+2.35
11 00	3.88	5.78	+1.90
11 10	2.94	4.58	+1.64
11 20	2.25	3.66	+1.41
11 30	1.83	2.92	+1.09
11 40	1.59	2.40	+0.81
11 50	1.40	2.02	+0.61
12 00	1.24	1.74	+0.50
12 10	1.10	1.48	+0.38
12 20	0.95	1.23	+0.28
12 30	0.83	0.98	+0.15
12 40	0.71	0.74	+0.03
1 40	0.29	0.42	+0.13
1 50	0.20	0.37	+0.17
2 00	0 15	0.34	+0.19
2 10	0 05	0.33	+0.28
2 20	0.03	0.23	+0.16
2 35	0.13	0.24	+0.11
3 55	0.01	+0.08	+0.07

Applying Newton's formula in the manner indicated in the example given, it will at once appear that the value of c is no longer constant. It will be found that for mercury c has an initial value of .071, taking 1 minute as the unit of time. This value diminished quite rapidly for the first half hour. At the end of $2^h\ 30^m$ it was found to be .024. Starting from $T=10^h\ 40^m$, it was found that the previous values had received a diminution of .015 at $10^h\ 40^m$, and a diminution of .005 at $12^h\ 40^m$. Between $1^h\ 40^m$ and $2^h\ 10^m$ the value of c in this experiment increased from .017 to .025.

In the experiment with water, the value of c decreased from .042 at $10^h\ 10^m$ to .024 at $12^h\ 40^m$, or taking the initial value of μ at $10^h\ 40^m$, the value of c decreased from .027 to .021. From $1^h\ 40^m$ to $2^h\ 30^m$ c had nearly a constant value of .016. It appears, therefore, from these experiments that Newton's law of cooling

fails entirely when the cooling body is a complicated system. Since, as equilibrium is approached, both the substances cooled are very often under a state of stress which is relieved quite suddenly, it is obvious that the law may easily give an erroneous constant, since the time is continually increasing, without a corresponding diminution in the value of μ.

The following method of investigation will be found to give results substantially the same as those obtained in the preceding discussion.

By Taylor's Theorem we have:

$$\mu = \mu_0 + \frac{d\mu}{d\tau}\tau + \tfrac{1}{2}\frac{d^2\mu}{d\tau^2}\tau^2 + \tfrac{1}{2}\cdot\tfrac{1}{3}\frac{d^3\mu}{d\tau^3}\tau^3 + \tfrac{1}{2}\cdot\tfrac{1}{3}\cdot\tfrac{1}{4}\frac{d^4\mu}{d\tau^4}\tau^4 + \tfrac{1}{2}\cdot\tfrac{1}{3}\cdot\tfrac{1}{4}\cdot\tfrac{1}{5}\frac{d^5\mu}{d\tau^5}\tau^5 + \&c.$$

In which (see Brünnow, Spher. Astron., 1865, p. 28),

$$\frac{d\mu}{dt} = \frac{1}{w}\left[\Delta^{I} - \tfrac{1}{6}\Delta^{III} + \tfrac{1}{30}\Delta^{V} - \tfrac{1}{140}\Delta^{VII} \pm \text{etc.}\right].$$

$$\frac{d^2\mu}{dt^2} = \frac{1}{w^2}\left[\Delta^{II} - \tfrac{1}{12}\Delta^{IV} + \tfrac{1}{90}\Delta^{VI} - \tfrac{1}{560}\Delta^{VIII} \pm \text{etc.}\right].$$

$$\frac{d^3\mu}{dt^3} = \frac{1}{w^3}\left[\Delta^{III} - \tfrac{1}{4}\Delta^{V} + \tfrac{7}{120}\Delta^{VII} - \tfrac{41}{3024}\Delta^{IX} + \text{etc.}\right].$$

$$\frac{d^4\mu}{dt^4} = \frac{1}{w^4}\left[\Delta^{IV} - \tfrac{1}{6}\Delta^{VI} + \tfrac{7}{240}\Delta^{VIII} - \tfrac{41}{7560}\Delta^{X} + \text{etc.}\right].$$

$$\frac{d^5\mu}{dt^5} = \frac{1}{w^5}\left[\Delta^{V} - \tfrac{1}{3}\Delta^{VII} + \tfrac{13}{144}\Delta^{IX} - \text{etc.}\right].$$

$$\frac{d^6\mu}{dt^6} = \frac{1}{w^6}\left[\Delta^{VI} - \tfrac{1}{4}\Delta^{VIII} + \tfrac{13}{240}\Delta^{X} - \text{etc.}\right].$$

$$\frac{d^7\mu}{dt^7} = \frac{1}{w^7}\left[\Delta^{VII} - \tfrac{5}{12}\Delta^{IX} + \text{etc.}\right].$$

$$\frac{d^8\mu}{dt^8} = \frac{1}{w^8}\left[\Delta^{VIII} - \tfrac{1}{3}\Delta^{X} + \text{etc.}\right].$$

$$\frac{d^9\mu}{dt^9} = \frac{1}{w^9}\left[\Delta^{IX} - \text{etc.}\right].$$

$$\frac{d^{10}\mu}{dt^{10}} = \frac{1}{w^{10}}\left[\Delta^{X} - \text{etc.}\right].$$

In which Δ_1 Δ_2 Δ_3, etc. represent the successive orders of differences of the observed functions,

Δ^{I} Δ^{II} Δ^{III}, etc. represent the differences opposite the functions.

For the odd differences,

$$\Delta^{I} = \frac{\Delta_1^{+\frac{1}{2}} + \Delta_1^{-\frac{1}{2}}}{2},\quad \Delta^{III} = \frac{\Delta_3^{+\frac{1}{2}} + \Delta_3^{-\frac{1}{2}}}{2},\quad \Delta^{V} = \frac{\Delta_5^{+\frac{1}{2}} + \Delta_5^{-\frac{1}{2}}}{2},\ \&c.$$

For the even differences, $\Delta^{II} = \Delta_2$, $\Delta^{IV} = \Delta_4$, $\Delta^{VI} = \Delta_6$, &c.

In order to obtain the differential coëfficients, we arrange the values of μ in three groups, in the manner indicated below:—

SERIES I.

FOR MERCURY.

μ_0							
26.95							
	−13.15						
13.80		+8.22					
	− 4.93		−5.56				
8.87		+2.66		+3.65			
	− 2.27		−1.93		−2.07		
6.60		+0.73		+1.56		+0.76	
	− 1.54		−0.37		−1.31		+0 39
5.06		+0.36		+0.25		+1.15	
	− 1.18		−0.12		−0.12		−1.15
3.88		+0.24		+0.13		+0.00	
	− 0.94		+0.01		−0.12		
2.94		+0.25		+0.01			
	− 0.69		+0.02				
2.25		+0.27					
	− 0.42						
1.83							

SERIES II.

FOR MERCURY.

2.25							
	−0.42						
1.83		+0.18					
	−0.24		−0.15				
1.59		+0.05		+0.13			
	−0.19		−0.02		−0.12		
1.40		+0.03		+0.01		+0.09	
	−0.16		−0.01		−0.03		+0.03
1.24		+0.02		−0.02		+0.12	
	−0.14		−0.03		+0.09		−0.35
1.10		+0.01		+0.07		−0.23	
	−0.15		+0.04		−0.14		
0.95		+0.03		−0.07			
	−0.12		−0.03				
0.83		+0.00					
	−0.12						
0.71							

SERIES III.

FOR MERCURY.

0.29		
	−0.07	
0.22		+0.00
	−0.07	
0.15		−0.03
	−0.10	
0.05		+0.08
	−0.02	
0.03		+0.12
	+0·10	
0.13		

SERIES I.

FOR WATER.

μ							
27.72							
	−9.40						
18.32		+4.10					
	−5.30		−2.14				
13.02		+1.96		+1.25			
	−3.34		−0.89		−0.79		
9.68		+1.07		+0.46		+0.55	
	−2.27		−0.43		−0.24		−0.50
7.41		+0.64		+0.22		+0.05	
	−1.63		−0.21		−0.19		+0.19
5.78		+0.43		+0.03		+0.24	
	−1.20		−0.18		+0.05		
4.58		+0.28		+0.08			
	−0.92		−0.10				
3.66		+0.18					
	−0.74						
2.92							

SERIES II.

FOR WATER.

3.66							
	−0.74						
2.92		+0.22					
	−0.52		−0.08				
2.40		+0.14		+0.04			
	−0.38		−0.04		−0.08		
2.02		+0.10		−0.04		+0.19	
	−0.28		−0.08		+0.11		−0.37
1.74		+0.02		+0.07		−0.18	
	−0.26		−0.01		−0.07		+0.27
1.48		+0.01		+0.00		+0.09	
	−0.25		−0.01		+0.02		
1.23		+0.00		+0.02			
	−0.25		+0.01				
0.98		+0.01					
	−0.24						
0.74							

SERIES III.

FOR WATER.

0.44		
	−0.07	
0.37		+0.04
	−0.03	
0.34		+0.02
	−0.01	
0.33		−0.09
	−0.10	
0.23		+0.11
	+0.01	
0.24		

If we compute from Series I and Series II the values of μ for Series III, the computed and the observed values will agree if Newton's law holds true. It will be found that this agreement does not take place. It will be noticed also that the mercury and the water reach the temperature of the air in which they are placed, in nearly the same time.

Our next inquiry will be whether the diminution in the value of the constant c, for falling temperatures, as observed in the case of mercury and water, also prevails in the case of solid metals when surface contact with the thermometers is maintained. Two experiments are selected in which the variations in the length of the steel bar R_3 are determined by end-measure comparisons with a steel bar in melting ice. In the first experiment, the steel bar R_3 was removed to the comparator after having been exposed to a liquid temperature of about 35°C. for a period of three hours. In the second experiment, the bar remained upon the floor of the basement during the preceding night and before removal had a temperature 2° less than that of the inner comparing room.

TABLE VII.

COMPARISON OF STEEL BAR R_3 WITH THE END-MEASURE BAR IN MELTING ICE.

Expressed in divisions of the micrometer, 1 div. = 0.202μ.

July 11, 1894 $10^h\ 12^m$; removed R_3 from 31° C. to comparing room at 20.°25C.

July 12, $8^h\ 9^m$; removed R_3 from 18°.35 to comparing room at 20°.21.

c = computed value of constant for thermometer.

c' = computed value of constant for the bar R_3.

I = normal length of the steel bar in melting ice.

COMPARISONS, JULY 11.

Time.	τ	(I—R)	(I—R) Red. to 0°C.	μ for τ	μ for (I—R_3)	c	c'
	°			°			
$10^h\ 30^m$	25.70	—296 div.	+513 div.	+5.45	—397 div.	. . .	. . .
11 35	25.07	—232	+545	4.79	—333	.026	.035
11 40	24.51	—193	+556	4.26	—294	.025	.030
11 45	24.02	—153	+569	3.77	—254	.025	.030
11 50	23.48	—131	+575	3.23	—232	.024	.027
11 55	23.33	—099	+582	3 08	—198	.023	.028
12 00	22.97	—073	+597	2.72	—174	.023	.027
12 05	22.64	—055	+599	2.39	—156	.024	.027
12 10	22.50	—038	+605	2.15	—139	.022	.026
12 15	22.22	—026	+606	1.97	—127	.023	.025
12 20	22.14	—0.14	+609	1.89	—115	.021	.025
12 25	21 93	—0.05	+612	1.68	—106	.021	.024
12 30	21.83	+0 06	+618	1.58	— 95	.021	.024
12 35	21.72	+0.16	+617	1.47	— 85	.020	.024
12 40	21.63	+0.22	+624	1.38	— 79	.020	.023
1 30	20.90	+0.75	+640	0.69	— 36	.018	.020
1 45	20.74	+0.82	+639	0.49	— 29	.018	.019
2 00	20.59	+0.83	+636	0.34	— 18	.018	.021
2 15	20.59	+0.84	+633	0.34	— 17	.017	.019
2 30	20 45	+0.93	+637	0.20	— 8	.018	.022
2 45	20.40	+0.94	+639	+0.15	— 7	.018	.021

COMPARISONS, JULY 12.

Time.	τ	(I—R_3)	(I—R_3) Red. to 0°C.	μ for τ	μ for (I—R_3)	c	c'
	°			°			
$8^h\ 30^m$	19.27	183 div.	664	+0.94	+78	. . .	. . .
8 40	19.42	164	638	0.79	+48	0.017	0.011
8 50	19.48	148	636	0.73	+41	.013	.011
9 00	19.62	140	639	0.59	+35	.016	.009
9 10	19.68	132	635	0.53	+27	.014	.008
9 20	19.74	127	635	0.41	+22	.014	.011
9 30	19.82	123	631	0.39	+16	.015	.007
9 40	19.86	121	633	0.35	+17	.014	.006
9 50	19.85	118	628	0.26	+17	.012	.005
10 10	19.94	116	631	0.27	+16	.012	.005
10 30	19.97	114	631	0.24	+ 9	.011	.004
10 50	20.05	108	628	0 16	+ 0	.013	.004
11 10	20.00	106	630	0.15	— 6	.011	.003
11 30	20.00	102	628	0.15	+ 1	.010	.003
11 50	20.05	105	627	0.10	+ 0	.009	.003
12 10	20.05	106	628	0.10	+ 1	.008	.001

We may derive the following conclusions from the results given in Table VII.

(*a*) In every case the value of *c* diminishes with the time, but the diminution is relatively less than in the experiments with the mercury and with water.

(*b*) Considering this experiment only, the rate of diminution is less for a rapid than for a slow change of temperature.

(*c*) The absolute value of the constant diminishes as the rate of change becomes less. It will be seen that the mean value of *c* for July 11 is more than three times the value for July 12. Of course the value will be affected by any accidental error in μ_0, but it will be found that substantially the same results will be obtained by assuming each of the values of μ in succession as the initial value for μ°.

(*d*) The time required for the bar R_3 to reach its normal length is substantially the same in the two series of observations.

(*e*) In the case of a rapid fall of temperature, the real relation between the length of R_3 and of the bar in melting ice when the value of $(I-R_3)$ is reduced to 62.°0 with the known coëfficient of expansion of R_3 is not reached till about $1^h\ 40^m$. In other words, under this condition the thermometer does not give the real temperature of the bar. On the other hand, in the case of a very slow change of temperature the normal relation at 62°.0 is reached in 10 or 15 minutes, and the thermometer does indicate the real temperature of the bar, although the bar does not reach the point of complete saturation till a much later time.

The examples given above may be considered as illustrative of a general law which appears to prevail when slow changes of temperature occur near the point of equilibrium under a nearly constant temperature. If it were not for one circumstance perhaps it would be correct to state the law as follows:—

After a mass of metal has remained at a nearly constant temperature for a considerable time, the inertia which must be overcome by any change of temperature, before a variation in molecular action takes place, seems to be much greater than after harmonic molecular action has commenced. In other words, the inertia of comparative molecular rest is much greater than the inertia of established molecular motion. The circumstance to which I refer relates to the uncertainty whether this observed effect may not be due to the relatively greater controlling influence either upon the thermometers or upon the metals compared, of the ob-

scure heat lodged in neighboring large masses of matter. A few cases have occurred in which the evidence seems to be very strong, that under certain conditions of slow variations of temperature, the thermometers, and, under certain previous thermal conditions of the bars themselves, the metal is brought into a state of stress. When this stress is overcome by increased molecular agitation, an almost instantaneous change in length takes place. In one case, the whole increment was made by a series of rather rapid pulsations. Still, I am obliged to say that I have been unable to ascertain the conditions in which the results described, can be invariably produced.

A striking illustration, either of the truth of the law stated above provisionally, or of the controlling influence of neighboring large masses of matter, occurred in the first of the two sets of observations of the steel bar R_3 given above. About two minutes were required for each complete comparison with the end measure bar in melting ice. The thermometer resting upon the surface of the bar was read at the commencement and the end of each observation,—the observer meanwhile remaining near the bar. Throughout the entire series a rise of from 0°.10 to 0°.15C. was observed between the two readings. This increment continued long after apparent equilibrium had occurred. But after a nearly constant temperature had been maintained for two or three days, the near presence of the observer was found to produce a far less effect. Indeed, the writer has endeavored in vain to produce in this way a rise of the mercury column amounting to 0°.05. Changes of this kind appear to be local and temporary in their effect. They are probably due to changes in the temperature of the air which forms an envelope about the exposed part of the bulb of the thermometer, and are nearly or quite balanced by the controlling effect of the contact of the bulb with the metal at a few points. The writer has never been able to detect any corresponding change in the length of the bar when the time of exposure fell within five minutes.

The existence of these varying thermal forces which seem to govern the process of cooling, as shown by the examples already given, ought to furnish an explanation of the periodic variations in the readings of thermometers when the comparisons are made at regular intervals of time. The existence of these periodic fluctuations in certain thermometers was pointed out in a paper read at the Cleveland meeting of the Association. The phenomena

described at that time have been confirmed by subsequent observations by different observers (see Physical Review, Vol. I, No. 2, p. 145).

Both the period of the cycle and the amplitude of the variations have been found to vary with different thermometers. In a few cases the double amplitude amounted to 0.°50. About one-half of the amount of these periodic movements of the mercurial column is easily accounted for. The remaining half must be attributed to controlling effect of the obscure heat stored in neighboring masses of matter. One disturbing element is the personal equation of the observer in estimating the tenths of the subdivisions of the scale of the thermometer. Errors of this class will be eliminated in the long run. Disturbances of another kind are introduced by the observer himself. When he enters the comparing room, a temporary change in the temperature of the air which surrounds the bulb takes place. When he leaves the room the cause of this local disturbance is withdrawn, but it continues to act for a considerable time either in harmony with or in opposition to the forces in action previous to his visit. Every subsequent visit modifies the original thermal effect due to a rise or fall of temperature, so that the curve which represents a uniform movement of the mercurial column under the action of an otherwise constant thermal force becomes periodic in its character.

The phenomena which take place in observations of this kind are well illustrated by the following experiment:—

Let a thermometer whose errors are well determined, be suspended in a rather small room whose height does not exceed seven or eight feet. After the temperature of the room has remained nearly constant for at least twenty-four hours, an observer enters the room and after remaining one minute, reads the thermometer and retires. This operation is repeated at regular intervals of five minutes. At the termination of the first visit a rise of *e. g.* 0.°15 is observed. The amount of the increase in height will diminish with each visit, and in a short time a permanent equilibrium will be established and will remain nearly constant as long as the visits are continued at the same intervals. But if new intervals are introduced, the subsequent readings of the mercurial column will exhibit periodic deviations from the values which would have been observed if the new disturbance had not been introduced.

The examples which have thus far been given are to be consid-

ered as illustrative of the action of thermal forces under conditions similar to those already described. In the brief time at my disposal, it will be impossible to make a critical examination of the action of obscure heat rays under the well defined thermal conditions which have been established. We must be content with a general statement of the results obtained.

As has already been stated, a long series of comparisons of meters upon bronze and upon steel, under varying conditions, was made in 1888–9. The observations have only been reduced since the commencement of the preparation of this address. The delay in reduction was deliberately decided upon, in order that in subsequent observations I might not be influenced by a knowledge of the conclusions now for the first time drawn from them.

The following designations are to be noted:—

The results for the bronze bar from readings of a thermometer placed longitudinally in the slot in the bar are designated B_1. Those which depend upon the readings of the thermometer which rests horizontally upon the surface of the bar, are designated B_2. Similarly, results for the steel bar are designated S_1 and S_2. The observed values of (B_1-S_1) and (B_2-S_2), are reduced to 62° by the coëfficient 3.82 μ for each degree Fahr.

The observations, which extend from Oct. 28, 1888, to Feb. 26, 1889, were made with the comparator of the form shown in Fig. 1, mounted in the room adjoining my lecture room in Recitation Hall. The following are the conditions under which the different series which form the body of the observations were made:

Series.	*Intervals.*		*Conditions.*
I.	1888 Oct. 20	Nov. 18.	Both bars rest upon supports at the neutral points, in a pine box painted black.
II.	Nov. 19	Nov. 22.	Bars rest upon paper supports placed upon the bed of the comparator.
III.	Nov. 23	Dec. 20.	Bars mounted in the box and covered with a wood cover during the night preceding the observations. During this series the effect of shields placed over the thermometers was investigated.

IV.	Dec. 21	Jan. 3.	Bars supported upon wood blocks $1\frac{1}{2}$ inches in height.
V.	Jan. 4	Jan. 15.	Bars supported on wood blocks $\frac{1}{2}$ inch in height. During this series the effect of introducing a painted wood slat between the bars was investigated.
VI.	Jan. 16	Jan. 21.	Slat left between the bars during the night preceding the observations.
VII.	Jan. 22	Jan. 27.	East window of the comparing room open during the night preceding. Fire in the adjoining lecture room during the night.
VIII.	Jan. 28	Feb. 6.	Windows of the comparing room closed during the night. Windows and shutters of lecture room left open.
IX.	Feb. 7	Feb. 20.	Shutters open, also windows of comparing room. Bars rest upon paper supports.
X.	Feb. 21	Feb. 26.	Bars rest upon wood blocks $1\frac{1}{2}$ inches in height.

Throughout the entire series the relative positions of the bronze and the steel bars upon the comparator have been noted. When the bronze bar is nearer to the observer than the steel bar its position is described by the letter F. Similarly, when the steel bar is in the rear of B, its position is designated by R. An increase of temperature during these observations is designated by I. Similarly, a falling temperature is denoted by D. Rising and falling temperatures between successive days are indicated by I′ and D′ The letter C denotes that the bars are in contact. C R I indicates that the bars are in contact under a rising temperature with the bronze bar in the rear and, similarly, for the remaining combinations.

Our first inquiry will relate to the real difference in length between the two meters derived from all the observations, 1957 in number, extending from Oct. 28, 1888, to Feb. 26, 1889. The reduction to 62° of every comparison will be made independently by the readings of the four thermometers, employing for the relative coëfficient of expansion the value $3.82a$ for each degree Fahr. The separate values of (B–S), which were obtained, are given in the following table: τ_1 and τ_2 represent the mean of the readings of the thermometers in the slots and upon the surface of the bars respectively.

TABLE VIII.

Limiting Dates.	τ_1	τ_2	No. Obs.	B_1	B_2	S_1	S_2	$\frac{1}{2}(B_1+B_2)$	$\frac{1}{2}(S_1+S_2)$	Means
	°	°								
Oct. 28 .. Nov. 25	65.47	62.79	128	7.1 μ	6.7 μ	6.6 μ	6.6 μ	6.9 μ	6.6 μ	6.7 μ
Nov. 6 .. Nov. 14	58.08	57.99	102	6.9	7.2	6.6	6.7	7.1	6.6	6.8
Nov. 15 .. Nov. 23	54.00	53.58	151	6.9	7.3	6.6	7.3	7.1	7.0	7.0
Nov. 25 .. Dec. 2	47.25	47.33	140	6.6	6.2	6.6	6.7	6.4	6.7	6.5
Dec. 3 .. Dec. 11	44.49	45.70	106	7.2	6.8	7.1	6.4	7.0	6.8	6.9
Dec. 12 .. Dec. 19	47.78	47.70	116	7.8	8.2	7.6	7.7	8.0	7.7	7.8
Dec. 21 .. Dec 27	39.29	39.80	150	7.9	6.3	6.8	6.3	7.1	6.6	6.8
Dec. 28 .. Jan. 4	48.95	48.95	145	7.0	6.9	6.3	6.4	7.0	6.4	6.7
Jan. 5 .. Jan. 13	42.41	42.46	134	6.8	6.7	6.8	6.7	6 7	6.7	6.7
Jan. 14 .. Jan. 22	32.89	32 98	148	7.0	6.7	6.3	6.0	6.9	6.2	6.5
Jan. 23 .. Jan. 29	38.06	37.97	172	7.2	7.3	6.8	6.9	7.2	6.9	7.1
Jan. 30 .. Feb. 5	27.51	27.71	152	7.2	6.6	6 9	6.7	6.9	6.8	6.8
Feb. 6 .. Feb. 13	28.86	29.02	150	7.2	7.0	6.9	6.4	7.1	6.6	6.9
Feb. 14 .. Feb. 25	35.98	36.15	163	6.2	6.9	7.0	7.1	6.5	7.1	6.8
			1957	7.1	6.9	6.8	6.7	7.0	6.8	6.9

It will be seen from this table that, whatever combinations may be made, the probable error of a single result rarely reaches 0.2 μ and that the value of the maximum deviation from the mean of the values in the last column is only 0.3 μ.

Second. During the daily observations, some new condition was generally introduced soon after the regular morning observations were completed. The effects of these new conditions are involved in the values given in Table VIII. In order to obtain the real difference in lengths from observations in which a given condition had been maintained for a considerable time, the results derived from the first set of observations, for each day only, are given in Table IX. They are grouped under the headings R and F.

TABLE IX.

GROUP.	LIMITING DATES.	B_1	B_2	S_1	S_2	$\frac{1}{2}(B_1+B_2)$	$\frac{1}{2}(S_1+S_2)$	MEAN.
				R				
I	Oct. 28 . . Nov. 10	6.7 μ	8.8 μ	6.5 μ	8.3 μ	7.7 μ	7.4 μ	7.6 μ
III	Nov. 21 . . Nov. 29	6.7	6.6	6.4	6.5	6.6	6.4	6.5
IV	Dec. 24 . . Jan. 3	7.8	7.3	6.9	6.9	7.5	6.9	7.2
V	Jan. 4 . . Jan. 15	6.7	7.0	6.4	7.4	6.8	6.9	6.9
VI	Jan. 16 . . Jan. 21	6.6	6.9	6.5	7.1	6.7	6.8	6.8
VII	Jan. 22 . . Jan. 23	7.7	7.3	7.5	6.3	7.5	6.9	7.2
VIII	Jan. 29 . . Feb. 6	6.5	7.3	6.7	7.2	6.9	6.9	6.9
IX	Feb. 7 . . Feb. 14	7.6	9.0	7.3	10.9	8.4	9.1	8.7
X	Feb. 21 . . Feb. 26	6.7	8.2	6.7	10.2	7.4	8.4	7.9
							Mean	7.3
				F				
I	Oct. 30 . . Nov. 18	6.3 μ	7.1 μ	5.9 μ	6.6 μ	6.7 μ	6.2 μ	6.4 μ
III	Nov. 19 . . Dec. 23	7.7	6.5	6.7	6.7	7.1	6.7	6.9
IV	Dec. 30 . . Jan. 2	6.0	6.7	5.3	5.4	6.3	5.3	5.8
V	Jan. 6 . . Jan. 13	6.6	6.8	5.9	6.2	6.7	6.0	6.3
VI	Jan. 18 . . Jan. 20	6.1	6.5	6.5	5.3	6.3	5.9	6.1
VIII	Jan. 24 . . Feb. 5	7.2	6.5	6.5	6.5	6.8	6.5	6.6
IX	Feb. 8 . . Feb. 15	6.9	8.0	6.4	6.9	7.4	6.6	7.0
X	Feb. 22 . . Feb. 25	6.2	6.8	6.7	6.8	6.5	6 7	6.6
							Mean	6.3

Mean value of (B—S) = $\frac{1}{2}$ (7.3 + 6.3) = 6.8 μ

It will be seen that this result differs from the result of the entire series by only 0.1 μ.

Third. This inquiry consists in the determination of the average amount of the diminution from the mean value 6.9 μ under a rising temperature and of the increase under a falling temperature.

The results are shown in the following table in which Δ T represents the rise or fall in temperature, and Δ B and Δ S represent the decrease for a rising and the increase for a falling temperature.

For a rising temperature.

Position of B.	ΔT.	ΔB.	ΔS.	Means.	
R	+17.5μ	—1.6μ	—2.7μ		
F	+11.1	—1.1	—3.2	—1.7μ	—3 0μ

For a falling temperature.

R	— 3.4	+2.2	+1.1		
F	— 6.0	+1.3	+1.5	+1.7	+1.3

The average change during the passage from a rising to a falling temperature is therefore 3.8 μ.

Fourth. The values of (B—S) in Table X will not only indicate the extent of the deviation of the mean value under the conditions imposed for each of the series of comparisons, but also under which the comparisons for each day were made.

TABLE X

CONDITION.	B_1	B_2	S_1	S_2	$\frac{1}{2}(B_1+B_2)$	$\frac{1}{2}(S_1+S_2)$	MEAN.
R. I.	6.7 μ	7.2 μ	6.1 μ	6.1 μ			
R. D.	6.7	8.2	6.9	9.3			
Mean.	6.7	7.7	6.5	7.7	7.2	7.1	7.1
R. I.	6.7	7.2	6.1	6.1			
F. I.	7.8	6.3	7.8	6.6			
Mean.	7.2	6.8	6.9	6.3	7.0	6.6	6.8
F. I.	7.8	6.3	7.8	6.6			
F. D.	6.5	7.2	5.6	6 5			
Mean.	7.1	6.7	6.7	6.6	6.9	6.7	6.8
R. D.	6.7	8.2	6.9	9.3			
F. D.	6.5	7.2	5.6	6.5			
Mean.	6.6	7.7	6.8	7.9	7.1	7.1	7.1
C. R. I.	6.7	5.8	6.3	5.3			
C. R. D.	6.6	7.0	6.6	7.7			
Mean.	6.6	6.4	6.5	6.5	6.5	6.5	6.5
C. R. D.	6.6	7.0	6.6	7.7			
C. F. D.	7.7	10.4	7.5	10.0			
Mean.	7.1	8.7	7.0	8.8	7.9	7.9	7.9
C. R. S.	6.8	7.9	6.7	6.4			
C. F. S.	7.6	6.9	7.4	7.1			
Mean.	7.2	7.4	7.0	6.8	7.3	7.0	7.1
C. F. I.	8.5	8.8	8.7	8.5			
C. F. D.	7.7	10.4	7.5	10.0			
Mean.	8.1	9.6	8.1	9.7	8.8	8.9	8.8
						Mean	7.0
R. D.′	6.5	7.2	5.9	7.4			
F. D.′	7.5	6.4	6.9	6.6			
Mean.	7.0	6.8	6.4	7.0	6.9	6.7	6.8
R. D.′	6.5	7.2	5.9	7.4			
R. I.′	7.7	8.9	8.2	9.5			
Mean.	7.1	8.6	7.1	8.4	7.6	7.7	7.6
R. I.′	7.7	8.9	8.2	9.5			
F. I.	3.5	7.8	1.9	5.1			
Mean.	5.6	8.3	5.1	7.3	6.9	6.2	6.6
C. R. I.′	6.2	7.9	6.2	8.0			
C. R. D.′	6.7	6.4	6.4	6.4			
Mean.	6.5	7.1	6.3	7.2	6.8	6.8	6.8
C. R. D.′	6.7	6.4	6.4	6.4			
C. F. D.′	8.3	8.3	8.3	8 0			
Mean.	7.5	7.3	7.4	7.2	7.4	7.3	7.3
C. R. S.′	6.8	6.8	6.7	6.2			
C. F. S.′	8.0	7.7	7.9	7.8			
Mean.	7.4	7.2	7.2	7.0	7.3	7.1	7.2
C. F. I.′	7.3	9.7	7.0	9.4			
C. F. D.′	8.3	8 3	8.3	8.0			
Mean.	7.8	9.0	7.6	8.7	8.4	8.2	8 3
						Mean	7.2

Mean value of (B—S) = ½ (7.0 + 7 2) =7.1 μ

It will be seen from an examination of this table that there is at every point a substantial elimination of the errors indicated in the typical example given at page 76.

It will be seen also that it is possible to reach a degree of precision in the comparison of standards of lengths under the ordinary variations of temperature, which is comparable with the most favorable conditions under a nearly constant temperature.

The comparator was mounted in the large comparing room of the new Shannon Physical Laboratory, March 24, 1890. A series of comparisons between the meters R_2 and R_3 was at once instituted, extending through March and April, but these observations have not yet been fully reduced. Work with the interferential comparator prevented a resumption of comparisons till November, 1893.

In the early part of that month the comparator was mounted upon insulated brick piers in the inner comparing room. The first work done in this new position consisted of 1015 comparisons of the meter R_2 and a meter laid off upon a bar made by Troughton Simms in 1885. This bar is identical in shape, dimensions and composition, with the Imperial Yard of Great Britain. The defining lines for a yard and a meter are traced upon the mirror surface of hardened steel plugs inserted in the bar. This bar is designated C_p. This series of observations extends from Nov. 22, 1893, to March 24, 1894. Especial attention was paid in this investigation to the effect of slow changes of temperature in effecting changes of lengths from the interchanged positions of the two bars. In a sufficient number of cases, a given temperature was obtained and held till the full effect of any desired change of thermal condition was investigated. In fact, almost every conceivable form of variation was investigated with reference to these bars.

The details of these investigations are necessarily omitted, but the results given in Table XI will furnish a criterion for an estimate of the degree of precision reached in this series of observations.

TABLE XI.

τ	(R_2-C) at 0° C.	τ	(R_2-C_p) at 0° C.	τ	(R_1-C_p) at 0° C.	τ	(R_3-C_p) at 0° C.
−7°	−0.8μ	+2°	−1.0μ	+ 9°	−1.1μ	+16°	−0.9μ
−4	−0.8	+5	−0.9	+10	−0.8	+17	−1.1
−2	−1.0	+6	−1.2	+13	−1.2	+18	−1.3
+0	−0.7	+7	−0.9	+14	−0.9	+19	−1.1
+1	−1.3	+8	−1.0	+15	−1.0	+21	−0.8
						+22	−0.5
						+25	−0.3
						Mean	−0.94

The observed values of $(R_2—C_p)$ have been reduced to 16°.67C. with the relative coëfficient 0.110 μ. It will be noticed that the greatest deviation from the mean value is 0.6 μ.

The extent of the deviation from the mean value depending upon the relative positions of the bars upon the comparator will be seen from the values of $(R_2—C_p)$ given in Table XII.

TABLE XII.

Position of $R_2 = F$.			Position of $R_2 = R$.			
Limiting Dates.		(R_2-C_p)	Limiting Dates.		(R_2-C_p)	Means.
1893, Nov. 21	Nov. 30	—0.6μ	1893, Dec. 1	Dec. 4	—2.8μ	—1.7μ
Nov. 30	Dec. 13	+0.4	Dec. 4	Dec. 7	—2.4	—1.0
Dec. 14	Dec. 16	+1.4	Dec. 7	Dec. 15	—2.9	—0.8
Dec. 17	Jan. 7	—0.3	Dec. 15	Jan. 7	—2.6	—1.4
1894, Jan. 7	Jan. 14	+0.0	1894, Jan. 7	Jan. 15	—1.0	—0.1
Jan. 15	Jan. 21	—0.2	Jan. 28	Feb. 3	—2.0	—1.5
Jan. 25	Feb. 5	—0.1	Feb. 6	Mar. 10	—2.7	—1.4
Feb. 5	Mar. 12	—0.4	Mar. 10	Mar. 12	—2.7	—1.5
					Mean	—1.2μ

The evidence of the effect of position upon the comparator is here unmistakable.

The persistence of the observed relation, after a change of temperature has become established, will be seen from the following example.

TABLE XIII.

For a slowly rising temperature.				For a slowly falling temperature.			
Dec. 3.	Time.	τ	(R_2-C_p)	Dec. 8.	Time.	τ	(R_2-C_p)
	$8^h\ 48^m$	13.3°	—2.2μ		$8^h\ 21^m$	22.2°	—1.2μ
	9 24	13.3	—2.6		8 57	22.1	—1.2
	9 54	13.4	—3.0		9 11	22.1	—1.4
	10 42	13.7	—3.2		9 41	21.8	—1.6
	11 30	14.3	—3.0		10 00	21.1	—1.2
	12 30	14.4	—2.8		10 45	18.8	+0.0
					10 55	18.3	—0.1
					2 30	16.6	+0.1

The following is given as an example of the effect of the near presence of the observer and of a sudden relief from a state of stress in the bar.

During this series, the observer stood continuously in front of

the comparator from $9^h\ 10^m$ to $10^h\ 4^m$ and from $1^h\ 9^m$ to $2^h\ 28^m$ The sudden change occurred between $1^h\ 30^m$ and $1^h\ 40^m$.

TABLE XIV.

Time.		τ	(R_2-C_p)	Time.		τ	(R_2-C_p)
		°				°	
9^h	10^m	6.9	-1.8μ	1^h	42^m	7.4	$+0.0\mu$
10	2	6.9	−1.8	1	52	7.4	+0.1
10	4	7.0	−1.6	2	3	7.5	+0.1
1	9	7.2	−1.2	2	11	7.7	+0.1
1	30	7.2	−1.8	2	22	7.7	+0.1
				2	28	7.7	+0.0

It appears, therefore, that the conclusion may be safely drawn from this entire series of observations, that the action of the ob scure rays of heat does not materially differ, when the bars compared have the same or different coëfficients of expansion, when they have the same shape and the same mass.

In order to ascertain whether the action varies with the mass of the bars compared, a résumé of an extended series of comparisons of R_2 with two Geneva Society meters will be given. One of these meters is the property of Brown University and was sent to me for investigation by Professor Blake. The other belongs to Haverford College and was sent to me by Professor Thompson. The bars are designated Bl. and Th. respectively. The observed relations with R_2 were reduced to 0°C. by means of the provisional coëfficient 18.55 μ. It appears from a determination of the absolute coëfficient that this value may be a little too small. The meter of the International Bureau is designated by A_0

TABLE XV.

CORRECTIONS TO METER Bl. AT 0°C.

	Limiting Dates.	No. Obs.	A_0—Bl.
1893,	Oct. 29 . . Nov. 3	23	$+32.8\mu$
	Nov. 5 . . Feb. 11	30	+30.8
	Feb. 11 . . Feb. 14	17	+32.1
	Feb. 14 . . Feb. 15	20	+33.5
	Feb. 16 . . Feb. 18	17	+32.1
		Mean	$+32.26\mu$

CORRECTIONS TO METER Th. AT 0°C.

	Limiting Dates.	No. Obs.	A_0—Th.
1893,	Oct. 29 . . Nov. 6	20	$+60.1\mu$
	Nov. 6 . . Feb. 12	21	+60.5
	Feb. 13 . . Feb. 14	18	+59.2
	Feb. 15 . . Feb. 16	14	+60.0
	Feb. 16 . . Feb. 18	19	+59.2
		Mean	$+59.80\mu$

Meter Bl. is therefore 32.3 μ shorter than the International Standdard at 0°C., and meter Th. is 59.8 μ shorter. In the determination of these corrections, the bars rested directly upon a plane surface. When supported at points nine inches from the ends, these corrections must be increased 5.5 μ. Unfortunately, the graduated surfaces are not plane under the latter method of support.

While the separate results given above agree fairly well, the separate comparisons from which these mean values were derived exhibit far greater discordances than are found in the comparison of bars having a rectangular shape. While the figure eight form takes the temperature of the surrounding air very quickly, it seems to more completely under the control of the obscure heat of the comparator. Exchanging the position of the bar from front to rear and *vice versa*, with respect to the bar with which the comparisons are made, seems to produce very little effect. While the readings of thermometers resting horizontally upon the ruled surface seem to give the real temperatures of the bars judging by the close agreement of the reduced relations, the results obtained at different times often exhibit a divergence as great as 5 μ or 6 μ.

Thus far our investigations have related to the relative changes in length which take place in one bar with reference to another bar considered as a standard at varying temperatures. We shall now make a similar investigation by comparing the standards selected, with an end-measure bar in melting ice. The meter upon the steel bar R_3 and a meter laid off upon plugs of silver inserted in the wall of the ways of the comparator which is nearest the observer have been selected for this investigation. It will be at once seen that we shall in this manner obtain the absolute coëfficients of expansion of steel and of iron. Moreover since the meter upon the silver plugs is connected directly with the mass of iron which forms the bed of the comparator, we ought to be able to obtain from these observations, sufficient data to enable us to form an approximate estimate of the extent to which it is possible for the obscure rays of heat stored in the iron to affect the temperatures of other metals having much less mass when they are placed in near contact with the larger mass.

Three inquiries must be made before we can obtain a correct estimate of the degree of reliance which can be placed upon comparisons made between a line-measure and an end-measure in melting ice.

First. To what extent can the end-measure be considered as a constant unit of length under the method of observation employed? Will not repeated contacts between the stops wear away the surfaces to an appreciable extent? The observations show that no measurable change will take place for a considerable time when great care is taken in making the contacts. In the series of observations which will be presently described, an apparent change in the length of the end-measure steel bar amounting to 4μ took place between June 18 and Aug. 3. During this time, the ice box, which weighs about forty-five pounds when filled with ice, was placed upon the comparator, and after several contacts had been made, removed to its place of support, about one thousand times. Altogether, about five thousand separate contacts were made. Previous to June 18 the ice box slipped from my hands and fell to the floor on three occasions. The evidence is fairly conclusive that the length remains constant for short intervals of time.

Second. Can the influence of the box filled with ice when placed upon the comparator during the time required for a complete observation, be neglected?

The time required to make a complete comparison between the two meters and the end-measure meter is about three minutes. The steel meter R_3 is placed about three inches from the middle part of the ice-box. The meter, designated S_p. upon the silver plugs, is a little below the bottom of the box and about one and a half inches distant. When the ice box is in position upon the comparator, a thermometer placed upon S_p will very quickly fall about 2° Fahr. When the ice box is removed, the mercury column rises to its previous position very quickly. Quite contrary to my expectation, it has been found that when the ice box is allowed to remain upon the comparator for a considerable time, the thermometers meanwhile occupying their usual positions, the observed relations, reduced with the observed readings of the thermometers, will not differ over 2μ or 3μ from the normal relation. This result has been obtained so frequently that there does not seem to be much doubt of its reality. For example: on April 29, 1894, continuous comparisons were made from $6^h\ 15^m$ to $9^h\ 8^m$ from which the following relations were obtained. At 0°C., R_3 was found to be 153.6μ shorter than the end-measure steel bar and the meter upon S_p was found to be 58.0μ shorter at 62°.0 Fahr. The ice box was then allowed to rest upon the comparator until $10^h\ 14^m$

At $10^h\ 16^m$, after the removal of the ice box, the observed relations were found to be 152.μ and 61.μ. The comparisons were then continued throughout the entire day at nearly regular intervals. In no case did the observed values for R_3 fall below 149.μ or rise above 153.μ It was found that the presence of the observer remaining in front of the comparator for two hours produced no deviations from the normal relation exceeding 1.8μ for R_3 and 0.5μ for S_p.

These results are similar in character to a result obtained from an observation made in 1891 with the interferential comparator. A meter upon a bronze bar having a cross-section of one and one-half inches was brought from complete saturation at —11° Fahr. and placed in the comparing room, beside one of the pair of bars employed in interferential observations. The distance between the bars was about three inches. The companion bar upon the refractometer was situated at right angles to this bar and about sixteen inches distant at the nearest point. It was found that no appreciable change in the length of the first bar was produced by the proximity of the cold bar during the first seven or eight minutes. A slow change was then observed, the maximum value of which was seven fringes, or $\frac{7}{800}$ of an inch. The bar was then allowed to become completely saturated at 136° Fahr. when an observation similar to the above was made. As before, no change in length was observed during the first eight or ten minutes. A slow change then took place *in the opposite direction*, amounting to 7.5 fringes, and this relation was maintained for several hours.

Third. To what extent can the constancy in the length of the bar in melting ice be depended upon, under wide variations in the temperature of the surrounding air?

An extended series of observations was made in order to answer this inquiry satisfactorily; with the result that if the ice box is packed solidly with fine ice, and if the water is withdrawn every half hour, the length of the steel bar will remain constant when the temperature of the air is 88° Fahr. For safety, twenty-five minutes was allowed for the bar to take the temperature of the ice

The entire series of comparison between R_3 S_p and I, extends from March 20 to August 3, 1894. In the observations made previous to May 23, the bar R_3 rested upon paper supports placed upon

the bed of the comparator. In the subsequent observations it rested upon blocks of pine wood having a height of one and one-half inches. The position of the bar upon the comparator remained unchanged throughout the entire series of observation. In this series, the effect of the obscure rays in changing the length of R_3 and S_p was sought to be obtained in four ways.

First. By a rapid change from one temperature to another temperature, which was maintained for any required length of time by means of the Sturtevant blower.

Second. By tracing the effect of placing a cast iron tank filled first, with ice and afterwards with water at varying temperatures in contact with the entire length of the comparator upon the side farthest from the position of the bar R_3.

Third. By placing the tank filled with water, first in contact with the comparator and subsequently at varying distances from it, under the natural temperature of the comparing room. Since the temperature of the water was, in consequence of evaporation, maintained about 0°.7 lower than that of the surrounding air, it was possible in this way, to ascertain the conduction effect and the consequent obscure heat effect due to the application of a constant supply of heat to the comparator.

Fourth. A similar experiment was tried directly with bar R_3. A galvanized iron tank having the dimensions $44 \times 1\frac{1}{2}$ inches and a depth of three inches, filled with water, was placed at distances from R^3 varying between $\frac{1}{16}$ and $\frac{1}{2}$ an inch. In this way it was possible to determine the effect of the differences of temperature amounting to 0°.7 constantly maintained in changing the length of the bar R_3. Finally, many observations have been made for the purpose of securing evidence relating to the apparent increase in the molecular inertia of the bars compared under nearly constant temperatures maintained for a long time.

I have already occupied too much of your time in this address. I shall therefore reserve the discussion of these observations for a future occasion. Meanwhile, I shall endeavor to verify by additional observations the conclusion which have been provisionally drawn from the results already obtained.

One result of this investigation however has so important a bearing upon the question under consideration that it deserves mention. It has been found that when the comparing room, after exposure to a nearly constant temperature for several days, has its

temperature quickly raised or lowered to a given point and when it is maintained at that point for a considerable time, the maximum variation from the normal length of R_3 occurs on the second day after the change has occurred, while in the case of S_p the maximum variation is reached on the third day.

Throughout this entire series of observations an attempt has been made to establish such temperature conditions as would eliminate from the final result the obscure heat effects in changing the lengths of R_3 and S_p. The extent to which this has been accomplished will be seen from an examination of Tables XVII and XVIII. The values of $(I-R_3)$ there given have been reduced with the coefficient 52.5 div. $= 10.60\mu$ for each degree C. The values of $(I-S_p)$ have been reduced to 62°.0 with the coëfficient 12.8 div. for each degree Fahr. Since the value of one division of the micrometer of this microscope is 0.485μ, the provisional value of the coëfficient is 6.21μ. The corrections given in the tables are to be applied to these values, giving for the adopted coëfficient of R_3 10.58μ and for the coëfficient of the iron of the comparator the value 6.28μ. These values are undoubtedly subject to a slight change, since they involve errors not completely eliminated in the widely varying temperature conditions established for a purpose quite different from that of obtaining the best value of the coefficient of expansion. For an exact determination of the coëfficent, the method employed would seem to be entirely adequate, if wide extremes of temperature are maintained with short intervals of time intervening. In order that it may be seen that this conclusion is legitimately drawn, the value of the correction to the coëfficient 52.5 div. for the steel bar R_3 will be derived from such observations as are the best suited for the determination of this element.

The results are given in Table XVI.

In series I of Tables XVII and XVIII, all the observations made between March 20 and Aug. 3 are included. In series II only those observations are included in which the conditions are measurably favorable to accurate results and which are, to a certain extent, free from the effects of previous thermal conditions. In the series from July 5 to Aug. 3 especial attention has been given to the effect of very slow changes of temperature. Attention is called to the fact that series I and series II give substantially the same values for the correction to the assumed values of the

coëfficients of expansion; a result which would not have been obtained if the effects of the obscure heat rays had not been pretty effectually eliminated by the temperature conditions established for the purpose of securing this elimination.

In conclusion, it will be in order to make the honest confession that I am by no means satisfied with the results of this investigation. With the experience already gained, I shall hope to be able to add something more to our knowledge of an obscure subject in the near future. It is my purpose to continue this investigation with the interferential comparator, constructed in accordance with the plan proposed by Professor Morley. In the instrument which has been constructed for this purpose, it has at last been found possible, after repeated failures, to maintain a vacuum indefinitely in the brass boxes which receive the bars to be compared.

Since it has been found feasible to make an automatic count of the number of fringes which correspond to a given change in length in the bars compared, the last practical difficulty in the application of this method disappears. Since, it will be easy to pass from air contact to a vacuum and *vice versa* at pleasure, it will at once be obvious that the new method presents great advantages in its application to a study of the various problems relating to obscure heat.

TABLE XVI.

Limiting Dates.	t	$(1-R_0)$ at 0°C.	Corr. to Coëfficient in div.	Corr. to Coëfficient in mikrons.
	°			
Apr. 13 . . Apr. 17	6.09	773.3 div.	+0.25	+0.05
	10.64	772.1		
Apr. 24 . . Apr. 30	9.84	764.1	+0.05	+0.01
	13.50	763.9		
May 1 . . May 14	14.85	733.2	+0.50	+0.10
	20.82	730.2		
May 15 . . May 21	16.08	711.9	—0.59	—0.12
	21.35	715.0		
May 23 . . June 10	15.11	669.1	—0.57	—0.11
	21.40	672.7		
June 11 . . July 7	15.11	651.0	+0.74	+0.15
	21.83	642.8		
			Mean	+0.01

TABLE XVII.

COMPARISON OF R_8 WITH THE END-MEASURE BAR I IN MELTING ICE.

SERIES I.

Limiting Dates.	No. Obs.	τ	$(I-R_8)$ at 0°C.	Corr. to Coefficient in div.	Correction in mikrons.
1894, Mar. 20 . . Apr. 5	30	3.90	+873.4		
	21	11.48	885.2		
	20	11.71	887.5	—0.50	—0.10μ
April 6 . . Apr. 15	15	6.55	+786.9		
	11	12.15	787.3	—0.07	—0.01
April 16 . . Apr. 30	52	8.63	+769.9		
	42	12.58	767.6		
	35	14.31	770.8	—0.17	—0.03
May 1 . . May 22	49	15.62	+731.8		
	53	20.31	735.9	—0.87	—0.18
May 23 . . June 17	112	16.35	+689.7		
	68	21.05	683.6	+1.30	+0.26
June 18 . . July 4	21	20.96	+674.5		
	57	22.44	677.4	—1.95	—0.39
July 5 . . July 16	45	20 46	+663.7		
	46	20.71	664 3	—2.40	—0.48
July 17 . . Aug. 3	27	20.30	+655.4		
	32	21.47	652.1	+2.65	+0.53
				Mean	—0.05

SERIES II.

Limiting Dates.	No. Obs.	τ	$(I-R_8)$ at 0°C.	Corr. to Coefficient in div.	Correction in mikrons.
1894, Mar. 20 . . Apr. 5	21	3.26	+862.9		
	6	10.23	868.0	—0.73	—0.15μ
Apr. 6 . . Apr. 15	10	5.85	+789.0		
	7	8.59	780.9	+2.96	+0.59
Apr. 16 . . Apr. 30	40	8.75	+771.4		
	35	12.84	767.6	+0.93	+0.19
May 1 . . May 22	47	15.73	+733.3		
	37	17.43	734.2		
	28	18.86	732.5	+0.26	+0.05
May 23 . . June 17	80	15.48	+681.6		
	49	19.82	689.4		
	50	23.18	685.3	—0.63	—0.13
June 18 . . July 4	21	20.96	+674.5		
	64	22.38	677.6	—2.17	—0.44
July 5 . . July 16	45	20.46	+663.7		
	46	20.71	664.3	—2.40	—0·48
July 17 . . Aug. 3	24	20.20	+655.2		
	32	21.47	652.1	+2.44	+0.49
				Mean	+0.01

TABLE XVIII.

COMPARISON OF S_p WITH THE END-MEASURE BAR I IN MELTING ICE.

SERIES I.

Limiting Dates.	No. Obs.	τ	(I–Sp) at 62.°0	Corr. to Coëfficient in div.	Correction in mikrons.
		°			
1894, Mar. 20 . . Apr. 5	38	33.49	+177.9		
	26	44.59	181.2		
	18	53.07	173.7		
	40	62.56	168.3	+0.45	+2.23μ
Apr. 6 . . Apr. 15	26	41.97	+140.2		
	33	49.54	138.4		
	10	54.19	142.5	—0.16	—0.08
Apr. 16 . . Apr. 30	57	45.80	+129.9		
	67	53.93	122.9		
	28	60.94	121.5	+0.55	+0.27
May 1 . . May 22	35	56.01	+110.1		
	112	61.05	110.4		
	45	65.84	95.8		
	96	73.97	97.6	+1.19	+0.59
May 23 . . June 17	64	57.64	+99.8		
	30	61.36	96.8		
	66	66.62	93.2		
	27	70.59	97.4	+0.32	+0.16
June 18 . . July 4	79	69.50	+85.4		
	63	72.08	88.0	—1.00	—0.49
July 5 . . July 16	42	67.97	+76.0		
	24	70.31	77.8	—0.77	—0.38
July 17 . . Aug. 3	18	67.02	+74.5		
	41	70.17	78.6	—1.31	—0.64
				Mean	—0.04

SERIES II.

Limiting Dates.	No. Obs.	τ	(I–Sp) at 62.°0	Corr. to Coëfficient in div.	Correction in mikrons.
1894, Mar. 20 . . Apr. 5	11	37.00	+184.3		
	15	49.38	167.9		
	26	63.02	167.9	+0.63	+0.30μ
Apr. 6 . . Apr. 15	28	41.96	+182.5		
	21	50.37	167.2	+1.82	+0.88
Apr. 16 . . Apr. 30	55	46.55	+162.8		
	50	48.77	158.8	+1.81	+0.88
May 1 . . May 22	39	57.71	+105.2		
	64	61.13	104.7		
	42	64.44	101.8		
	35	71.53	102.5		
	40	73.45	107.6	—0.11	—0.05
May 23 . . June 17	48	58.95	+94.3		
	41	62.59	93.1		
	61	68.50	95.5	+0.12	—0.06
June 18 . . July 4	68	70.79	+87.5		
	71	71.92	86.9	+0.53	+0.26
July 5 . . July 16	42	68.64	+77.5		
	22	70.09	78.2	—0.48	—0.23
July 17 . . Aug. 3	16	67.52	+74.8		
	24	70.93	77.6	—0.82	—0.40
				Mean	+0.19

PAPERS READ.

ON ELECTRIC STRENGTH. By G. W. PIERCE, Univ. of Texas, Austin, Texas.

[ABSTRACT.]

AT the Madison meeting of the American Association for the Advancement of Science, Professor Alexander Macfarlane and the writer contributed a paper on the electric strength of solid, liquid, and gaseous dielectrics, in which it was maintained that for a thin stratum of air or other gas between two parallel metal plates the electrostatic gradient when the spark passes is less, the greater the distance between the plates; but for paraffined or bees-waxed paper this gradient is constant; it is also constant for paraffin oil or kerosene. Later Mr. Pierce has made other experiments, particularly with solid and melted paraffins of different melting-points, which seem to confirm the conclusion that the electric strength of solids and liquids is constant.

The anomalous behavior of the gas appears to be due to convection. This belief was strengthened by observing that when particles of dust or other solid impurities were suspended in the liquid, convection was sometimes started and the results obtained for the liquid showed a decided weakening of the dielectric as the length of spark was increased. On the assumption of convection, considering the energy of the system regarded as a condenser, an equation was obtained for the gas giving the potential difference in terms of the square root of the sum of multiples of the square and first power of the distance between the plates, — similar to the equation previously obtained experimentally by Dr. Macfarlane.

Also, the writer observed that with a given e.m.f. a spark would pass much farther along the surface between a solid and a gaseous dielectric than it would through the uninterrupted gas. When pieces of glass, broken so as to expose a smooth edge, were placed flat between one pair of the discs, it was found that the ratio of the spark in free air to that of the spark along the surface was very approximately constant, as expressed by the equation —

$$r = .442\,s;$$ where

r = sparking distance in air,

s = sparking distance along the surface between glass and air.

By neglecting this fact that a gaseous dielectric is weakened by the presence of a solid dielectric, some experimenters on the electric strength of air, among them Mr. Steinmetz, who kept his plates at a constant distance by pieces of glass or mica of measured thickness, have obtained results for the lengths of spark

that are probably too great for the given differences of potential. Multiplying Mr. Steinmetz's striking distances by .442, the ratio of r to s above, brings them into close correspondence with the results obtained by Baille, Alex. Siemens, Bourne, De la Rue and Müller, Sir Wm. Thomson, Dr. Macfarlane, and others.

[To be printed in full in The Physical Review.]

A PHONOGRAPHIC METHOD FOR RECORDING THE ALTERNATING CURRENT CURVE. By C. J. ROLLEFSON, Ithaca, N. Y. Presented by Dr. Bedell.

[ABSTRACT.]

To produce the alternating current curve by the aid of the phonograph two operations are necessary. First, a record of the curve must be produced on the wax cylinder of the phonograph; second, this record produced in the first operation must be magnified by means of a suitable multiplying arrangement. The method seems especially adapted for the study of harmonics in the alternating current. By the aid of König's apparatus the number of harmonics present may be determined, and, perhaps, their relative intensities. Their relative positions may then be determined by plotting the curve. These operations may be repeated several times, and thus each operation may serve as a check on the others.

[To be printed in full in The Physical Review.]

STUDIES OF THE LIME LIGHT. By Prof. EDWARD L. NICHOLS and MARY L. CREHORE, Ithaca, N. Y.

[ABSTRACT.]

THE experiments to be described in this paper deal with the changes which the radiation in the incandescent lime cylinder used in the Drummond light undergoes from the moment of ignition until the lime has reached its final state of incandescence. The work was divided into two parts, in the first of which the total and light-giving radiation were separated from one another by the method of Melloni. By means of a galvanometer of high sensitiveness time curves of the total radiation and of those rays which were capable of being transmitted through water were obtained. The ratio of these duly corrected gave the radiant efficiency of the source which is also expressed as a function of the time. It was found that the radiant efficiency diminished from about fourteen per cent at the moment of ignition to about eighty per cent.

The second part of the investigation consisted of a study of the visible rays, wave-length by wave-length, for which purpose a simple form of spectrophotometer was used. The results are expressed by means of time curves showing the decadence of various wave-lengths of the spectrum, and by means of curves of relative distribution in the spectrum of the lime light at selected times after the first ignition of the cylinder.

[To be printed in full in The Physical Review.]

THE INFLUENCE OF HEAT AND ELECTRICITY UPON YOUNG'S MODULUS FOR A PIANO WIRE. By MARY C. NOYES, Ithaca, N. Y.

[ABSTRACT.]

THE object of the investigation was to determine the effect of rise of temperature upon Young's Modulus for a piano wire. Instead of using steam or hot oil to secure the various temperatures, as has been done by most who have worked on this subject, an electric current from a storage battery was employed. The current was sent through a magnetizing coil surrounding the wire, through a non-inductive coil, and through the wire itself. The temperatures ranged from 16° to about 200°. The wire was placed horizontally on a comparateur, fastened firmly at one end and passed over an Atwood wheel at the other. The elongations were determined by means of two microscopes which read to $\frac{1}{4000}$ of a millimeter; the wire tested was about 90 cm. long. Two sizes of wire were used, which were 0.4 mm. and 0.26 mm. in diameter. The results led to the formula, $M_t = M_0 (1 - at)$ The value found for a was 0.0005 for the larger wire, and 0.00046 for the smaller one. The results were practically the same when the magnetizing and the non-inductive coils were used, showing no appreciable effect from longitudinal magnetization.

When the wire was heated by a current through it the results were quite irregular, but were generally such as to show an appreciable increase in the modulus as compared with its value at the same temperature secured by the other method. The first current which heated the wire to a temperature between 30° and 40° generally produced an increase of about one per cent in the modulus as compared with its value at from 15° to 20° without any current.

The work was done in the Physical Laboratory of Cornell University, under the direction of Prof. Edw. L. Nichols.

[To be printed in full in The Physical Review.]

A PROBLEM IN STEREOSCOPIC PERSPECTIVE. By Prof. W. LECONTE STEVENS, Troy, N. Y.

[ABSTRACT.]

THIS paper is a development from an investigation, published by the writer some years ago in the American Journal of Science, on Physiological Optics, in which he described a new mode of stereoscopy. The method is to employ a pair of perfectly similar diagrams, of which the binocular combination is made to appear convex or concave at will by varying the relation between the visual lines and the planes of the two halves of the stereograph. A geometric explanation was given, which was true so far as it goes, but which the author now finds to have been insufficient.

A brief explanation of principles is given, and the method of stereoscopy is shown by use of diagrams and stereoscopes.

ON THE DIRECTED VELOCITY OF THE PARTICLES IN THE ELECTRIC ARC. By Prof. BENJ. W. SNOW, Madison, Wis.

[ABSTRACT.]

Two carbons bored out and placed horizontally were connected with the terminals of an alternating electric lighting circuit, and the image of the arc, as seen through the hollow core of the carbon was projected upon the slit of a spectroscope. A bit of iron burned in the arc produced a brilliant iron spectrum. The light entering the slit consisted, therefore, of intermittent flashes produced as the discharge in the arc approached the instrument or receded from it. Had the velocity of approach or recession been as great as one mile per second, the lines of the specimen would have appeared either double or broadened by an amount approximately equal to the one-hundredth part of the distance between the D lines. As no such displacement or broadening was observed, it is concluded that the velocity of the particles in the arc must be not greater than this amount.

ON THE RADIATION OF OBSCURE HEAT BY A METALLIC MASS. By Prof. BENJ. W. SNOW, Madison, Wis.

[ABSTRACT.]

A MASS of cast iron weighing one hundred pounds, heated to 100° C., or cooled to 0° C., was placed near one of the bars of the interferential comparater, and the expansion or contraction of the bar was noted. It was found that at first but little effect was produced. Soon, however, the bar expanded or contracted according to the temperature of the mass near it, and reached a maximum nearly two hours after the mass was placed in position. The bar then tended to resume its normal length, and reached that condition not less than twenty-four hours after the effects of the mass had first been detected.

A CALORIFIC EFFECT OF THE VELOCITY OF MIGRATION OF HYDROGEN IONS. By Prof. SAMUEL SHELDON, Polytechnic Institute, Brooklyn, N. Y.

[ABSTRACT.]

THE inability of H ions to travel beyond a certain velocity results in a heating of the cathode if sufficient E. M. F. is applied so that Faraday's Law requires the H to migrate faster than its maximum velocity.

[To be printed in The Physical Review.]

ON SOME MAGNETIC CHARACTERISTICS OF IRIDIUM. By Prof. S. H. BRACKETT, St. Johnsbury, Vt.

[ABSTRACT.]

THE paper is an account of examinations and tests of iridium showing characteristics which do not appear to have been noted before. The iridium was prepared by John Holland and stated by him to be free from iron.

In the magnetic field a bar is more readily magnetized transversely than longitudinally, ordinary stroking methods of magnetizing producing very irregular distribution of magnetism.

The magnetic intensity is as 1 to 12 compared with that of steel. The largest bar used was about 2½ cm. long. Special apparatus was constructed to test the permeability which was found to be practically unity.

Position or movement in a magnetic field is not sufficient to magnetize it, but it must be jarred. Being magnetized in that way in contact with poles of an electro-magnet and using different strengths of current, its curve of susceptibility was plotted and shown.

Examination of distribution was made by small suspended magnets and the fields plotted are shown.

Apparatus was constructed for magnetizing by *octuple touch*.

The field around the bar as magnetized transversely is shown by enlarged photographs of filings.

Low permeability, great coercitive force, and a magnetic intensity not recorded before are claimed as results of the author's investigation.

[Paper to be printed in The Physical Review.]

DEVICE FOR COMPARING NATURAL WITH TEMPERED MUSICAL SCALES. By MORRIS LOEB, Ph. D., University of the City of New York.

[ABSTRACT.]

As far as known to the author, the comparison of musical scales with each other is solely effected by direct mathematical tabulation or by a fixed diagram, constructed specially for each individual comparison.

A universal sliding scale can be constructed by laying off, upon the edge of one board or sheet, lengths corresponding to the number of vibrations per second of tones corresponding to various scales of tempered intonation. Upon another board is drawn a protractor, consisting of an angle of convenient aperture, subdivided by lines, in proportion to the major or minor scale. An appropriate mechanism guides this second board in such a manner, that the outer edges of the protractor will always coincide with the lines corresponding to an octave upon the first board. The inner lines of the protractor will then indicate on the first board the positions of the notes of the true intonation.

[The device itself was shown.]

DEFINITION OF MOTION. By Prof. J. W. POWELL, Bureau of American Ethnology, Washington, D. C.

[ABSTRACT.]

THE paper sets forth an attempt to define motion in such manner as to form, in connection with a definition of the attributes of matter, a basis for a classification of the categories of the real world. The doctrine of the conservation of energy is adopted and extended; for an attempt is made to show that when the law that action and reaction are equal is analyzed it is found to carry the corollary that the sum of motion possessed by each atom is constant, the apparent variability in motion being variability only in direction of motion.

THE ATTRIBUTES OF MATTER. By Prof. J. W. POWELL, Bureau of American Ethnology, Washington, D. C.

[ABSTRACT.]

THE purpose of the paper is a definition of the primal attributes of matter in such manner as to yield a basis for a system of classification of the categories of the real world. The attributes recognized are (1) number, (2) extension, (3) motion, and (4) duration.

ALUMINUM VIOLINS. By Prof. ALFRED SPRINGER, Box 621, Cincinnati, O.

[ABSTRACT.]

AN aluminum violin was exhibited to show the difference in quality of tone when the back and belly of the instrument were strengthened by arching and ribbing.

THE PHOTOGRAPHY OF MANOMETRIC FLAMES. By Prof. WILLIAM HALLOCK, Columbia College, New York, N. Y.

[ABSTRACT.]

WHILE occupied with a research upon the use of the nasal cavity in singing, which had been suggested by Dr. Floyd S. Muckey, and was largely carried out by him, it became desirable to record our results by photographing the manometric flames which we used.

For the attempted analysis of the voice, with and without the use of the nasal cavity, we arranged a set of König resonators, each having a manometric capsule in the back of it, connected by a rubber tube to the series of small gas burners, situated one above the other. The resonators were tuned to Ut_2 and

its first seven over-tones, Ut_3, Sol_3, Ut_4, Mi_4, Sol_4, number "7," and Ut_5. The whole arrangement was identical with the familiar apparatus of König.

The flames being viewed in a rotating mirror appeared as a bright line when that particular resonator was not responding, and as a wavy line when the air in the resonator vibrated, and caused the membrane of the manometric capsule to vibrate also, and the flame to jump up and down.

It is impossible to photograph what one sees in the rotating mirror on account of the irregularities of the mirror and its rotation, hence some other method of recording the jumping of the flame must be devised. Professor Merritt[1] has accomplished it by causing the sensitive plate to travel across the back of the camera, so that each jump of the flame would have its image fall upon a new part of the plate, and thus be successively recorded. It might be possible to cause the lens to move across the front of the camera and thus accomplish the same result.

In our case a camera was mounted upon a piece of board which was pivoted approximately under the optical centre of the lens, thus enabling us to rotate the camera about the centre of the lens. When the camera is so rotated, the image of any object in front of it will traverse the plate and be photographed as a line or otherwise as the case may be. A large black screen was so arranged on the stationary part of the apparatus that the flames, and the flames only, were visible to the camera through a slit about an inch wide in the screen, directly in front of the camera in its central position.

The method of operating was as follows: The camera was focused upon the flames. The cap may be left off all the time, and no stop is needed. The plate-holder is put in the camera, which is directed toward the black screen on one side of the slit. When all is ready and the flames are behaving properly, (which is seen in the rotating mirror,) the slide is withdrawn from the plate-holder, and the camera quickly rotated through about 90 degrees, until it is directed at the screen on the opposite side of the slit; the slide then is replaced in the holder, and the plate is ready for development. The 8 flames of our apparatus record themselves either as straight lines or as wavy lines according as their resonator may or may not be responding to an overtone, present in the voice or not. The record is made while the camera "sees" the flames through the slit in the screen. Springs were arranged to rotate the camera at definite and constant velocities, but it was found that it could be rotated with the hand quite well enough. When a poor lens (not rectilinear) is used, or great accuracy is necessary in the comparison of the number of vibrations in any two notes, two momentary exposures of the plate to the flames, with the camera at rest, and so stationed that the images fall once on one edge of the plate, again on the opposite edge, will give the fiducial points from which to count, eliminating any distortion due to the lens. By this means very common lenses may be used, with very large apertures.

Heretofore it has been considered necessary to increase the actinic power of the little flames by surrounding them with oxygen, or other means. We found this unnecessary if we took the precaution to turn up the flames until a characteristic bright point appeared just at the top of the blue. We used an old 4 x 5 camera with a fair 5 x 7 lens, and Cramer's "isochromatic *C*." dry plates

[1] Ernest Merritt, Physical Review, vol. I. p. 166, 1893.

with ordinary developer. One good plate was obtained with a plano-convex 3 inches diameter, 8 inch focus, using the full aperture. (The lens cost 50 cents.)

THERMAL CONDUCTIVITY OF COPPER AT LOW TEMPERATURES. By R. W. QUICK and B. S. LANPHEAR, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THE metal upon which this investigation was conducted was electrolytic copper placed in the form of a prismatic bar, $3' \times 2'' \times \frac{3}{4}''$. The method employed was fundamentally that of Forbes, which necessitates obtaining two curves, *viz.*: the curve of final distribution of temperature along the bar when one of its ends is maintained at a constant low temperature, and the time curve of heat absorption of the bar.

The temperatures of the bar were measured by means of the resistance of an electrolytic copper wire .002 in. in diameter, wound upon a copper collar which fitted the bar closely, but yet admitting of movement along it. This wire (about 9 ohms resistance) formed an arm of a slide bridge provided with a compensated resistance. The temperature coefficient of the wire was obtained by observing its resistance at the freezing-point of mercury and at the melting-point of ice.

In obtaining the data for the curve of distribution of temperature along the bar, the latter was placed in an air-tight box of wood and glass, whose dimensions were about $4' \times 15'' \times 15''$. The dew-point of the atmosphere within this box was reduced to a very low temperature to prevent deposition of frost on the bar when one of its ends was subjected to the temperature (about —77 C.) of a saturated solution of carbon dioxide snow in ether. The copper collar was moved to any position of the bar by aid of two small iron rods extending into the box.

To obtain the time curve of heat absorption, the bar was placed in a closely fitting tin box which was surrounded by an air chamber into which the cooling mixture was introduced. When the collar, which had been previously placed on the bar, indicated a sufficiently low temperature, the bar was removed from the cooling apparatus and placed under the same conditions that existed in the previous experiment, without exposing the surface of the bar to air other than that whose dew-point had been rendered very low by aid of a drying apparatus.

The following table gives the absolute values of conductivity of copper, obtained over the range —13° to —55°:

TEMPERATURE.	CONDUCTIVITY.
—53.9° C.	.933
—44.0	.948
—36.0	.971
—29.6	.995
—24.5	1.017
—19.0	1.027
—13.6	1.043

The equation which most nearly expresses the relation between conductivity and temperature over the range investigated is

$$K_t = 1.087\ (1 + .0028t),$$

which indicates an increase of conductivity with increase of temperature.

THE INFRA RED SPECTRA OF METALS. By E. P. LEWIS and E. S. FERRY, Baltimore, Md.

ON MAGNETIC POTENTIAL. By Dr. FREDERICK BEDELL, Cornell Univ., Ithaca, N. Y. [Paper to be printed in The Physical Review.]

ON THE SOLUTION-TENSION OF METALS. By HARRY C. JONES, Johns Hopkins Univ., Baltimore, Md. [Paper to be printed in The Physical Review.]

THE THERMAL CONDUCTIVITY OF CAST IRON. By Prof. J. THORNTON OSMOND, State College, Penn.

THE INFLUENCE OF TEMPERATURE UPON THE TRANSPARENCY OF SOLUTIONS. By Prof. EDWARD L. NICHOLS and MARY C. SPENCER, Cornell Univ., Ithaca, N. Y. [This paper will be printed in The Physical Review.]

A NEW FORM OF SPECTROPHOTOMETER. By Prof. EDWARD L. NICHOLS, Cornell Univ., Ithaca, N. Y. [This paper will be printed in The Physical Review.]

SOME PECULIAR LIGHTNING FLASHES. By ALEXANDER MCADIE, U. S. Weather Bureau, Washington, D. C.

LIGHTNING AS A CASE OF THE DISSIPATION OF ENERGY. By N. D. C. HODGES, 874 Broadway, New York, N. Y.

A NEW RECORDING THERMOMETER FOR CLOSED SPACES. Illustrated by a working model. By Prof. W. H. BRISTOL, Stevens Institute, Hoboken, N. J.

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ADDRESS

BY

PROF. THOMAS H. NORTON,

VICE PRESIDENT, SECTION C.

THE BATTLE WITH FIRE, OR THE CONTRIBUTIONS OF CHEMISTRY TO THE METHODS OF PREVENTING AND EXTINGUISHING CONFLAGRATION.

INTRODUCTORY.

Amongst the many myths of ancient Greece, none have fascinated the people of all times more than that of Prometheus. It kindled the tragic muse of Æschylus; has been interwoven in the poetic expression of nearly all Aryan races; has enchained the fancy of youth to our own time, and has offered to the student of folklore a rich mine of speculation and comparative study. Of all the deeds of the Greek hero, the one which appeals most closely to the man of science is that of the theft of fire from the gods, and its bestowal upon mankind, placing within its grasp the whole sequence of material and intellectual development dependent upon this one factor.

Like many other great gifts, that of the Titan brought with it, alongside its marvellous possibilities, a train of new dangers, terrors and responsibilities. While we can conceive of no serious advance along the path of civilization without the aid of fire, it is equally certain that its possession involves more watchfulness, greater dread, and more extended loss and suffering than any other element of our complex modern life.

From the scriptural utterance "Behold how great a matter a

little fire kindleth!" to the clang of the alarm bell in Schiller's "Lied von der Glocke," literature teems with allusions to the slavery of fear going hand in hand with dependence upon the "indispensable servant;" while the history of every great city is punctuated with the record of fire's visitation.

In common with the physicist, the engineer and the economist, society has summoned also the chemist to aid in the solution of the problems in connection with protection from fire. There is, in fact, a singular appropriateness in this call, for the whole structure of our chemical theory is based upon the fundamental study of the phenomena of combustion; while, as an ever-faithful servant, it has been the prime factor in the acquisition of nearly the entire mass of knowledge comprised in the term chemistry.

I have felt it desirable on this occasion to direct your attention to a brief review of the services which the chemist has thus far rendered in the battle with fire, to the field of investigation still open, to the methods of testing and experimentation in this branch, and to the application of fact already gained to American conditions. In the choice of this subject, I have, in common with some of my predecessors, left the domain of pure science to consider more closely certain economic aspects of chemistry, and enter, to some extent, into the province of chemical engineering, which is now recognized in our leading schools as entitled to distinct and separate treatment. A further reason which has influenced me is the practical absence, to this time, in our works of reference, of any attempt to collate and classify the knowledge gained in this field.

IMPORTANCE OF THE SUBJECT FOR AMERICA.

The prime importance of a more efficient protection against fire in our country has hitherto been overlooked by the mass of publicists and economists. The history of the cities of the old world throws a lurid signal to us from the past: London's great fire of 1666 involving a loss of 13,200 houses, and $54,000,000; Dresden almost totally destroyed in 1491; Hamburg's loss of 4,200 buildings in 1842; Moscow's loss of 18,000 buildings in 1752 and 31,000 in 1812; the great fires of Venice in 1106, Edinburgh in 1700 and St. Petersburg in 1862; the terrible visitations of such oriental cities as Canton, Yeddo and Yokohama, and more especially Constantinople, fireswept nineteen times during the past cen-

tury and a half, with a total loss of 160,000 houses. The fire record of our own young country during the past sixty years is, however, rich in warnings. In 1835, New York's largest fire covered fifty-two acres; in 1845, Pittsburg was nearly destroyed; in 1851, three-quarters of St. Louis was devoted to flame; Boston has had five great fires, the one of 1872 covering sixty-five acres; while Chicago's fire of 1871 was the greatest of modern times, covering 2,124 acres, destroying 17,430 buildings, and rendering 98,500 homeless.

The total annual loss of insured property by fire is about $200,000,000, and of this sum nearly one-half occurs in the United States,—$90,344,075 in 1893. Foreigners marvel at this reckless disregard of the immense losses by fire shown by our countrymen, for from eighty to ninety per cent of the 15,000 fires which occur annually can be traced to easily preventable causes, and chiefly to faulty construction. Consider, for a moment, the tax which is being paid this Moloch. Our total loss of property amounts to one-fifth of the net profits of all the industries of the country. Propose to a trader or manufacturer coolly to throw one-fifth of the annual profits into the grate! Yet this is what our productive industries as a whole have been and are doing in an unconcerned, if not cheerful manner. The direct loss by conflagration is, however, not the only factor. Our fire departments and water supply cost us $30,000,000 annually; while the loss of wages to mechanics and other productive forces, and numerous contingent amounts, swell the actual total loss to a most serious sum. The fire department of London costs but one-third of that of New York City; and the same ratio applies to most European cities. During a residence of ten years in French and German cities, I saw the fire engines called out but five times; while the average resident of an American city is apt to witness a call at least once a week. England's annual fire bill is but little over $10,000,000.

With these facts in view, is it not time to call a halt, to bring all the forces of science to bear in the battle, and redeem our America from what is nothing more or less than a servile bondage?

If we seek the reason for this vast difference in relative fire loss between the Europe of to-day and America, it is not to be found in a superiority of facilities for extinguishing conflagrations. The equipment of American fire departments is far better than that of the fire departments abroad. It results simply from the fact that

the European architect and builder have profited from the experience of the past, and learned that prevention is better than cure. The prevalent method of construction in New York is such, architects assure me, that the business part of the city awaits only the proper combination of circumstances to be the scene of a conflagration rivalling that of Chicago.

Before leaving these general considerations, it should be said that there are many hopeful indications of an awakening from this apathy, and ample recognition should be made of the earnest effort, inaugurated of late years in New England, to lessen fire risk; the application of the so-called slow burning principle of construction, especially to factories. By the adoption of this principle it has been possible to reduce insurance rates from 1½–2½% down to ⅞ of one per cent.

FIRE EXTINGUISHERS.

Passing to the more specific treatment of the subject, we find that, as in medicine, so in the matter of protection against loss by fire, there are two distinct lines of action: prevention and cure, or the adoption of such measures as to render an outbreak of fire difficult, and a conflagration practically impossible; and the provision of the proper facilities for the rapid subjugation and limitation of fire under full headway. As in medicine, also, there is a growing conviction that the prophylactic treatment is the more important. It is hence particularly in this direction, that the activity of the chemist has been chiefly called into play.

Let us first briefly review the methods of extinguishing fire.

In this field, but little has been done to add to the efficacy of the agent used from time immemorial—ordinary water. In addition to its cheapness and universal distribution, water possesses over other liquids peculiar advantages for the purpose in view—high specific heat and the formation of a vapor which is non-poisonous. Sulfur dioxid has been used to some extent; in fact it is an old-fashioned method in European countries to extinguish burning chimneys by kindling sulfur on the hearth. A quicker production of the gas is effected, more particularly for use in confined spaces, by introducing receptacles of burning carbon disulfid; and cylinders of liquid sulfur dioxid, have, under similar circumstances, been successfully employed. The advantage in the use of this gas consists entirely in its exclusion of the air nec-

essary to maintain combustion. The slower diffusion consequent upon high density renders it superior for this purpose to other available gases. This advantage is, however, largely counterbalanced by its irritant, poisonous nature; and it has never been accepted as one of the recognized agencies of general application.

Of much greater value is carbon dioxid, the efficacy of which is likewise based upon its ability to prevent the access of air to the material in process of combustion. The ease with which this is accomplished is shown by the familiar experiments of our lecture courses in chemistry. For practical results in dealing with ordinary fires, it is found best to employ a highly charged aqueous solution of the gas. Such solutions as those prepared for use as a beverage, have frequently been used in emergencies. One large soda-water establishment has been able to extinguish several fires in its own factory and in the neighborhood by the prompt use of the carbonated water in its receptacles. A quick-witted pharmacist recently extinguished a serious fire in his store from benzine by quickly using a pailful of soda-water drawn from his own fountain, the case being one in which simple water would have failed to accomplish the purpose.

The so-called chemical fire-engines, now regularly used in our public fire departments, are all constructed upon the principle of charging a quantity of water when used with carbon-dioxid and ejecting a stream of the carbonated water by the pressure of the gas itself. In the size most frequently employed the supporting truck carries two cylindrical tanks of steel or copper holding about 80 gallons of water and 28 pounds of sodium-bicarbonate with a leaden jar containing 14 pounds of sulfuric acid. At the moment of using, by a simple mechanical device the acid is admitted to the solution and a pressure of 140 pounds to the square inch is developed. The tanks are charged alternately while in operation so that it is possible to maintain a continuous jet of $\frac{1}{4}$ inch. The whole apparatus is light and easily drawn by two horses. There is also in use a combined manual and chemical fire engine devised by Foster. The pumps fill, with water, the compartments in which the chemicals are dissolved and whence the solutions come together in a generating chamber where the gas is evolved. Such engines are capable of throwing per minute 30 gallons of water containing 250 gallons of carbon dioxid to a distance of 90 feet. This type is also arranged for connection with high pressure mains.

Very careful tests carried out in 1883 showed conclusively the great value of a small quantity of carbonated water in extinguishing fierce flame, especially in a confined situation and when combustion had not penetrated much beneath the surface. The same principle was applied earlier by Baragwanath and others, in a variety of forms, to portable extinguishers. Dick's extinguisher, largely used in England, is a cylindrical tank of 7 gallons, easily carried on the back, giving a pressure of from 70 to 120 pounds, and possessing a projectile range of 50 feet. The peculiar feature of this type is the storing of the sulfuric acid in a glass container which is easily broken when the apparatus is to be used. Zabel's apparatus, like Dick's, is charged with sodium bicarbonate, but the acid used is contained in a cylinder from which it is liberated by simple inversion. Devices essentially the same have been introduced by Masnata and VanWisker. In Cartier's extinguisher the sulfuric acid is replaced by tartaric acid.

Platt's extinguisher has been successfully used for many years, and is valued on account of its simplicity; the turning of a valve and the inversion of the apparatus bringing it at once into operation. Other efficient extinguishers of American origin are the Babcock, the Harkness and the "Climax." In the latter, sulfuric acid is replaced by oxalic acid, and in both the Harkness and "Climax" the carbonated solution is forced out by a pump. The Babcock extinguisher is filled with a solution of sodium bicarbonate, and has in its upper part a vessel of acid suspended by lateral pivots to a stirrup depending from the top of the apparatus. The stopper of this vessel is worked by a rod through the top of the extinguisher. By withdrawing the stopper the vessel tilts over and mingles the acid with the solution producing at once the necessary pressure.[9]

The most recent and perhaps most efficient of chemical extinguishers is that introduced in 1893 by Dr. Henry P. Weidig, and extensively tested throughout our country during the past twelve months. It is adapted not only for portable use, but also for replacing ordinary town engines and for permanent installation in factories and on board ships, etc.

The apparatus consists of a steel vessel containing liquid carbon dioxid so arranged that it may be brought in connection with a receptacle filled with carbonated water, or a solution of ammonium carbonate, under any desired pressure. The carbonated water

meets in its exit pipe with a stream of ammonia gas emanating from a cylinder of liquid anhydrous ammonia. The carbon dioxid is thus bound in the form of the soluble salt, ammonium carbonate. The solution thus formed is forcibly ejected, and on reaching a fire the heat not only volatilizes the water but decomposes the salt so that a mixture of steam, carbon dioxid and ammonia is the result. One volume of water will yield under these circumstances twenty-five volumes of the two latter gases.

The principle of rapidly filling a confined space where fire has broken out with inert gases has been extended to the use of the gaseous products issuing from the combustion under boilers. In certain industrial establishments devices are introduced by which the current of the mixture of nitrogen, carbondioxid and aqueous vapor can be directed at will into a given apartment. The results are quite effective, combustion being promptly and permanently stopped. Other additions than carbon dioxid to the water used in extinguishing fires have proved of doubtful utility when submitted to practical tests. The list of such proposed additions includes potash (Kaiser), clay (Glaser), a mixture of sodium sulfite and four parts sodium alum (patented 1884 in Austria by Trotha and sold in the form of cartridges), salt, alum, waterglass, copperas, Glauber salts, borax, magnesium chlorid, sodium phosphate and soda.

Ammonia gas alone has been recommended. Its lightness and irritant properties render it, however, much less efficient than carbon dioxid or sulfur dioxid.

Hand grenades,[9] consisting of glass bottles, usually of a spherical form, charged with aqueous solutions of various chemicals, have found their way of late years into somewhat extended use. They are conveniently arranged in the corridors of large buildings, and are intended for use in extinguishing incipient outbreaks of fire. The grenade is to be thrown with such force into the center of combustion that it breaks and scatters its contents upon the burning material. The salts present are supposed to act by either giving off incombustible gases or by incrusting the burning articles, thereby excluding air. In practice, however, it is found that these grenades render but slight service, as they are frequently unbroken when thrown, especially against non-resistant substances. They are supposed to be charged with strongly carbonated water, or with a saturated solution of ammonium chlorid, sodium chlorid, sulfite or thiosulfate. Analysis, however, shows quite a variety of

composition in the contents. Sir Frederick Abel[7] in 1881 found one to contain a strong solution of salt and waterglass. Geissler examined three current types with the following results:[12]

Hayward's grenade: Gross weight 1120 g.; weight of liquid, 750 g.; composition, an aqueous solution of 15.7% $CaCl_2$ and 5.6% $MgCl_2$.

Harden's grenade: Gross weight 900 g.; weight of liquid, 555 g.; composition, aqueous solution of 19.5% NaCl and 8.9% NH_4Cl.

Schonberg's grenade: Gross weight, 770 g.; weight of liquid, 440 g.; composition, an aqueous solution of 1.66% Na_2CO_3 and 6.4% NaCl.

It may be noted in passing that the salts in these grenades cost about 1% of their selling price.

Finally mention should be made of extinguishing powders,[9] the use of which is literally a fighting of fire with fire. They are well devised to produce, by rapid combustion at the expense of the oxygen in saltpetre, a sufficient volume of inert gas—chiefly sulfur dioxid and carbon dioxid—to prevent the circulation of air about a fire, and thereby cut off the supply of atmospheric oxygen for further combustion. Their application is of necessity limited to small enclosed spaces without many openings for ventilation, and they have been found chiefly valuable in drying rooms where easily volatile products are being driven off, as in connection with the manufacture of oilcloth. The ingredients are coarsely powdered and readily ignited. They are often packed in cartridges and provided with fuses. They burn without explosion with a bright white flame, a strong odor and much smoke. Each pound yields about 4.8 cubic feet of gas, which consists of 2.3 pts. SO_2, 1.1 pts. CO_2 and 1.4 pts. N. One pound should be used for every 240 cubic feet of an enclosed space. The composition of the best known of these powders is as follows:

Bucher's powder	KNO_3	60 parts.
	S	36 "
	C	4 "
Heeren's powder	KNO_3	63 parts.
	S	29 "
	C	4 "
	Fe_2O_3	4 "

Schweizer's powder	KNO_3	58 parts.
	S	36 "
	C	3 "
	Fe_2O_3	1¼ "
	SiO_2 (sand)	75 "
Gruneberg's powder	KCl	20 parts.
	KNO_3	50 "
	S	50 "
	MnO_2	1 "
	Rosin	10 "
Zeisler's powder	KNO_3	60 parts.
	S	36 "
	C and CaO	4 "
Johnston's powder	Equal parts of KCl, KNO_3, MnO_2 and Rosin, moistened with waterglass and pressed into briquettes.	
Phillips' Fire Annihilator (introduced in 1851.)	KNO_3	60 parts.
	C	20 "
	$CaSO_4 + 2H_2O$	5 "

This latter was pressed in the form of a hollow brick. The central cavity contained sugar, and potassium chlorate and a vial of sulfuric acid, the latter so arranged as to be easily broken by a simple mechanical device. The brick was usually placed within a double cylindrical receiver containing water, so that the ignition of the powder caused not only the evolution of a large volume of gas, but also, by its heat, a liberation of a considerable amount of aqueous vapor.

In reviewing this portion of our subject it would appear that but few opportunities are afforded the chemist for further contributions of value. It would seem advisable, however, to study the feasibility of extending the use of carbon dioxid along lines similar to those in which automatic sprinklers have found such satisfactory application. In many factories and in numerous stores and warehouses the sprinkler, while most effective in quenching flame or hampering its progress, causes serious damage to manufactured products or materials for manufacture. The advantages of carbon

dioxid over water under these conditions are manifest. It is not difficult to conceive of a system of piping, opening naturally at the level of the floor, through which either automatically or under the control of a watchman, a powerful current of the gas could be directed into any apartment where flame was apparent. In the many cases where the losses by water do and would naturally far exceed the losses by direct combustion, there is but little doubt that the use of the invisible, inert, harmless gas would enormously limit the destruction of valuable property.

We come now to the most important division of our subject, namely, the methods of preventing loss or suffering by fire through the use of structural materials, textile fabrics and the like, which are either entirely incombustible or slowly combustible or from which the property of rapid combustion has been largely removed by special treatment. A structure built entirely of stone, brick, iron, cement, etc., is an illustration of the first type. A structure of brick with heavy beams of wood, heavy floors of plank, no hidden air-spaces, and a general absence of the lighter forms of wood work, illustrates the second type,—the slow combustion construction. The third type is to be found in an edifice of wood, the component parts of which, either by impregnation or by suitable coatings, have lost the property of ready inflammability.

The study of the choice of materials and their most efficient grouping as employed in the first and second methods of construction, apart from architectural considerations, falls purely within the domain of the mechanical engineer. It involves the question of strains and stresses under ordinary conditions and under the conditions of an elevated temperature.

It is in the special field of rendering such easily combustible substances as wood and the vegetable fibres used in textile fabrics more or less resistant to flame that the chemist has been able to render service.

Could our methods of building be limited to the completely fireproof or the slow burning system of construction, and interior decoration and equipment be restricted to the use of non-combustible materials, it is evident that the chemist would have but little to do. But mechanical considerations, canons of taste and questions of outlay will for a long time to come sustain the extended use of wood in the erection and finishing of many classes of edifices, especially of our homes. The beginnings of our towns and cities are almost

entirely in wood, and the same may be said of the suburbs of our centers of population. It will be many years before the rural residence and the home of the laborer in America will be as universally constructed of non-combustible materials as in Great Britain, France, Germany and other European countries. In such a country as Japan it is almost impossible to imagine any general departure from the time-honored and picturesque national construction of bamboo. The restriction of fabrics to fibers of animal origin is likewise out of the question.

In noting the historical development of the work of the chemist in the field as above outlined, we will first consider the methods which have been applied to textile fabrics and paper, and next those which have been used to render wood uninflammable.

TREATMENT OF TEXTILES AND PAPER.

The first experiments in this direction were made in England in 1735 by Obadiah Wild[2] who secured a patent for rendering the cartridge cases used by the navy resistant to flame. This process consisted of the addition of a mixture of alum, borax and copperas, to the paper pulp employed. Early in the present century the subject attracted the attention of several chemists. De Hemptine of Belgium in 1821 made quite an extended study of mixtures similar to that of Wild, and other substances. At the same time Brugnatelli recommended the use of potassium silicate, Hermbstadt of ferrous sulfate, De Lisle of an unnamed compound.[2] Gay Lussac[1] was deeply interested in the subject. In 1830 as the results of his experiments, he recommended the use of various chlorids, phosphates, borates, tartrates and carbonates without, however, considering the difficulties involved in their application on a large scale. The employment of the alkaline carbonates was later urged strongly by Prater, while Fuchs[2] and Bethel in 1838 advocated waterglass and others gypsum. Several patents were taken out during this period by the different investigators. Still later Chevalier recommended the use of a mixture of borax and ammonium sulfate. The use of ammonium sulfate alone was proposed by De Breza in 1838, and that of ammonium chlorid by Froggant in 1857. In 1855 M. Salomon[7] of Paris submitted to the English Board of Ordnance a process for rendering canvas uninflammable. It consisted of immersing the materials for a day in each of the following baths:

I.	Aluminum sulfate,	30 pts.	II.	Dry calcium chlorid,	20 pts.
	Glue (gelatin),	10 "		Glue,	10 "
	Water,	60 "		Water,	70 "

The interaction involved the formation of gypsum and aluminum chlorid which in turn precipitated the gelatin and converted it into a leatherlike insoluble substance. The object was to fill the pores of the fabric with gypsum and cover the surface with a hard binding material. Sir Frederick Abel. in reporting on the feasibility of this process found that it rendered the canvas very difficult of ignition, but that it also gave to it a degree of rigidity and harshness which forbade its use. In 1856 Maugham[7] patented the use of ammonium phosphate and starch; and in 1857 Thouret[7] patented the use of a mixture of three parts of ammonium chlorid and two parts of ammonium phosphate, adopting these proportions on account of cheapness although the ammonium phosphate alone gave most excellent results.

During this period the importance of better protection for the scenery of theaters was recognized. After a serious fire in the Berlin opera house, the custom was inaugurated of soaking all scenery in a strong alum solution.[29] In 1857 a commission in Paris carefully examined the subject, and in accordance with their recommendations the order was issued to have all scenery in theaters impregnated with waterglass.[29] After the lapse of some years it was found that scenery thus treated possessed but slight resistant power. The explanation advanced is that the waterglass on drying contracts steadily until the solid particles finally sit very lightly on the yarn of the canvas. Another is that a solvent action is exercised by the water in the water-colors often used by scenic artists. It has been suggested by Hexamer that the impregnation with waterglass could be advantageously followed by treatment with hydrochloric acid, thus precipitating silicic acid directly in the fibers of the yarn, a process practically similar to that of the use of mordants in dyeing.

Versmann and Oppenheim[2] in 1859 reported to the British Association for the Advancement of Science the results of an elaborate and extended study on the use of salts in treating fabrics, including some forty different substances in the range of their experimentation. Their tests were made on muslin free from starch, weighing

33.4 grains to 12 square inches; and more in the direction of ascertaining the strength of the most effective solution, rather than the weight of a given salt absorbed. After immersion in a solution the excess was removed by pressing and not by wringing. Tests were conducted on a large scale in muslin works and laundries. None of the salts recommended to that time were found available where the operation of ironing was to be performed. Either a smooth surface could not be obtained, or the material was injured on the application of heat.

The valuable results of Versmann and Oppenheim may be briefly summarized as follows:—

KCN—very effective in a 10% solution, but poisonous and expensive.

Na_2CO_3 and K_2CO_3—both very effective in a 10% solution, but the one is efflorescent and the other deliquescent.

$NaHCO_3$—very effective in a 6% solution, but CO_2 is rapidly lost and the protective power disappears.

$Na_2B_4O_7$—very effective, but on warming, boric acid is liberated and attacks the fabric.

NaOH—effective in 8% solution.

Na_2SO_4—no effect.

$NaHSO_4$—20% solution is protective, but the stuff is gradually attacked.

Na_2SO_3—25% solution is protective, but the stuff is gradually attacked.

Na_2HPO_4—a saturated solution is effective, but the fabric becomes perfectly stiff.

Na_2SiO_3—the fabric is strongly attacked and the appearance affected.

Na_2SnO_3—protective, but attacks the fabric.

$(NH_4)_2CO_3$—too volatile.

$(NH_4)_2C_2O_4$—renders the fabric combustible.

$(NH_4)_2B_4O_7$—a 5% solution gives good protection, but the acid is easily liberated and corrodes.

$(NH_4)_2SO_3$—a 10% solution is very effective, but the salt is deliquescent.

NH_4Cl—a 25% solution gives excellent results, but stiffens the fabric.

$(NH_4)_2HPO_4$—gives excellent results alone or when mixed with NH_4Cl as in Thouret's patent. Maugham's mixture of this salt

with starch was not available on account of uneven distribution throughout the mass.

$(NH_4)_2SO_4$—when rendered perfectly neutral by a little $(NH_4)_2CO_3$, this yields the best results of all the ammonium salts. Chevalier's mixture of this salt and borax attacks fabrics at a summer temperature.

$SnCl_2$
$SnCl_4$
$SnCl_4\ 2NH_2Cl$ } All these are good protectives, but attack the material.

The following salts give good protection when used in solutions of the strength indicated, but are not available on account of price or corrosive or other properties: $BaCl_2$ 50% sol., $CaCl_2$ 10%, $Al_2 3SO_4$ 77%, $KAl\,2SO_4$ 33%, NH_4Al2SO_4 25%, $FeSO_4$ 53%, $CuSO_4$ 18%, $ZnSO_4$ 20%, $ZnCl_2$ 8%.

Unsuccessful attempts were made to fix upon the fibers such protective salts as $BaSO_3$, $Al_2 3PO_4$, and various silicates. ZnO and Al_2O_3 gave good results, but would not adhere when washed. SbOCl was effective and withstood water, but not soap or soda. Stannous borate, phosphate and arsenate gave good protection and withstood washing but gave a yellow tinge to the fabric. Zinc and calcium stannates, while efficient protectors, would not withstand soap or soda. Stannic oxid was fixed permanently but imparted a yellow color. It seemed to be well adapted for coarse material, sail cloth, canvas, etc.

For light stuffs, to be ironed, sodium tungstate was found to be the best agent, and the most effective solution is one of 28° Tw. or 1.14 sp. gr., containing also about 3% of sodium phosphate in order to prevent the formation and precipitation of the acid tungstate.

Where the hot iron is not to be applied directly, ammonium sulfate can be advantageously employed in a 10% solution. The fabric is to be dried in chambers; the ordinary colors on prints, except madder purple, are unaffected.

Versmann and Oppenheim at first sought to produce, artificially, conditions similar to those existing in animal fibers such as silk and wool, which are not inflammable, and which contain about 18 % of nitrogen. Experiments to incorporate nitrogenous substances such as glue or albumen into vegetable fiber were without practical result, although it was found possible by the use of urea to intro-

duce into muslin 13% of nitrogen, rendering it thereby uninflammable.

Essentially the same object is obtained, as we have seen, by the use of ammoniacal salts.

Sir Frederick Abel[7] made reports in 1859 and 1860 to the English Ordnance Department on Versmann and Oppenheim's results, especially with reference to the protection of canvas. The advantages of sodium tungstate for light fabrics were fully confirmed by him. The availability of stannic oxid for sailcloth was likewise confirmed. Sailcloth was most effectively deprived of its inflammability thereby, and the protective agent was permanently fixed in the fabric, being affected neither by friction nor by repeated washing, while the strength of the canvas was not diminished. The only objections to the use of stannic oxid were: first, the notable increase in weight amounting to 50% of the original weight of the canvas; and, second, the comparative costliness. While the first objection was regarded by Abel as practically inseparable from the permanent fire-proofing of fabrics, the second he considered much more serious. Accordingly, we find him, shortly after, patenting and submitting to the Ordnance Department, a cheaper process for fire-proofing canvas, consisting of the deposition in the fiber of a double silicate of sodium and lead. Boiling solutions of basic lead acetate and of waterglass were used. I have not been able to ascertain how extended a use was made of this process. Abel in his reports states that he finds saturation with a solution of waterglass alone an efficient protective; but that its value is temporary only. He sums up the difficulties to be encountered in fire-proofing fabrics as follows:

(1) The protective material renders the fabric harsh and rigid; or (2) it absorbs moisture and keeps the fabric damp; or (3) it affects the strength and durability of the fabric; or (4) it is easily detached by rubbing or shaking; or (5) it is soluble in water and must be renewed after wetting.

In 1870 Abel[7] recommended to the Ordnance Department treatment with calcium chlorid for rope mantelets on board warships in order to keep them damp and prevent ignition during the firing of guns.

In 1871 the Austrian chemist Patera[4] introduced the use of magnesium borate as a protective for fine fabrics and delicate colors. The materials are soaked in a bath of 3 parts of borax and

2½ parts of magnesium sulfate in 20 parts of water with the necessary amount of starch, then wrung between cloths and dried. For coarser stuffs he found mixtures of ammonium sulfate and gypsum effective.

In 1882 a special committee of the Franklin Institute of Philadelphia reporting on safety devices for theaters gave the results of their experiments on the fire-proofing of scenery and gauze.[7] They obtained the best results with the material devised by Dr. J. Papen of Frankfort, Germany. The details of its composition are not given, but it has rendered excellent results in the Frankfort opera house, yielding efficient protection; not altering in time, nor affecting the strength or color of the fabrics, and producing no injurious effect on the voices of singers or actors. The committee obtained also very good results from the use of ammonium sulfate, of silica precipitated on the fiber, and from the processes of Gantsch and Judlin, details of which are also lacking.[7]

This question of fire-proofing scenery, etc., in theaters, had already been the subject of considerable investigation. In 1877 a committee of the House of Commons took evidence on the matter, and we find Mr. Henderson of the Criterion Theater testifying that he used regularly sodium tungstate in the preparation of new scenery; although it was not available for old scenery.

A committee of the London Society of Arts[7] in 1883 made a report on the same subject, recommending sodium tungstate as the best safeguard for scenery. They found on investigation, that the scenery in nearly all London theaters was treated with some fire-proof preparation; most having as a basis a borate or a silicate. They add in their report: "these compositions do not prevent the evolution of gas when an article is exposed to sufficient heat; and the gas takes fire and burns. When the external source of heat is removed, no more gas is evolved, and combustion ceases. Prepared articles burn when exposed to sufficient heat, but do not support combustion. One effect of this is that it is very much more difficult to set such materials on fire; and this either prevents the breaking out of the fire, or renders it much more easy to deal with when broken out."

The theaters of Paris had already used largely for protecting scenery, a solution of the following composition devised by Martin and Tessier:[21]

Ammonium sulfate, . .	8
Ammonium carbonate, . .	2

Boric acid, ...	3
Borax, ...	1
Starch, ...	2
Water, ...	100

Among recently introduced preparations for the purpose in view, the efficacy of which has not been fully tested, are the following:

Vendt and Herard,[11] 1885. A solution of 8 parts ammonium chlorid, 10 parts ammonium sulfate, 2½ parts sodium thiosulfate, 4½ parts of borax, and 72 parts of water.

Winckelman:[20]—Manganese chlorid, 33 parts
Glacial phosphoric acid, 20 "
Borax, 10 "
Magnesium chlorid, 12 "
Magnesium sulfate, 25 "

Fabrics are boiled for six hours in this solution and become thoroughly impregnated with insoluble double salts.

Martin and Tessier:[20]—Boric acid, 6 parts.
Borax, 3 "
Ammonium chlorid, 15 "
Water, 100 "

Used chiefly for cordage, sailcloth, canvas, and straw, the materials being steeped in the solution.

Vogt:[20]—Ammonium chlorid, 2 parts.
Zinc sulfate, 1 "
Water, 20 "
Starch as needed.

Subrath:[20]—Alum, 5 "
Ammonium phosphate, 5 "
Water, 90 "

Hattin:[20]—Calcium dihydrogen phosphate, ammonia, and gelatinous silica.

Pereles:[20]—Combined solutions of sodium phosphate, silicate and tungstate.

Nicoll:[20]—Solution of alum, borax, sodium tungstate and dextrin, or equal weights of calcium acetate and chlorid in hot water.

These comprise the processes for the protection of fabrics introduced up to the present time. As is easily seen, the use of sodium tungstate, the borates or ammonium salts alone or in mixtures is the striking feature.

A few words with regard to the methods of manufacturing or protecting paper are here in place.

Martin and Tessier[20] used the following bath for paper whether printed or unprinted:

Ammonium sulfate,	8 parts.
Boric acid,	3 "
Borax,	$1\frac{7}{10}$ "
Water,	100 "

The solution is placed in a vat, at the end of the paper-making machine and kept at 50 °C.

Paper thus treated is non-inflammable. The value in many kinds of business of a totally incombustible paper is easily appreciated; and several varieties, all based on a large use of asbestos, are in vogue. L. Frobeen's paper is made from 9 % of asbestos and 5 % of wood pulp mixed in water containing borax and glue. For ink he uses a mixture of platinum chlorid and india ink.

Halfpennig's paper[20] is made from 1 part vegetable fiber, 2 parts asbestos, $\frac{1}{10}$ part borax and $\frac{1}{5}$ part alum, formed in the ordinary way into a pulp to which waterglass is sometimes added. A paper of great flexibility and strength is obtained by coating sheets of linen on both sides with the incombustible paper. His ink is a mixture of graphite, copal, copperas and indigo sulfate.

Paper is also made from pure asbestos and from asbestos mixed with alum, aluminum sulfate, zinc chlorid and resin soap.[20]

A fireproof writing ink is an ammoniacal solution of silver nitrate, with a little india ink, while platinum chlorid mixed with lampblack and varnish is employed as a fireproof printing ink.[20]

METHODS FOR RENDERING WOOD UNINFLAMMABLE.

In taking up next the history of the efforts to render wood non-inflammable we encounter two distinct methods of procedure. The first is impregnation by the solutions of the chemical compounds which are to be operative, and includes such variations as the precipitation of insoluble salts within the wood by double decomposition; the second is the covering of the exterior of wood by protective coatings. In the case of existing structures, the latter is evidently the only means available.

The first recorded effort to protect wood was made at Munich in 1823, during the rebuilding of the Royal Opera House after de-

struction by fire [8, 18]. On the recommendation of Professor Fuchs all of the woodwork then received several coatings of waterglass. The surface covered was 400,000 square feet, and the cost was $1,000 or at the rate of $1 for 400 feet. Professor Fuchs prepared his solution by treating ten parts of caustic alkali, fifteen parts of infusorial earth, and one part of charcoal, with water. A somewhat similar composition was also in vogue then in England. It was made by grinding in oil one part of fine sand, two parts of wood ashes, and three parts of slaked lime; and was applied with a brush. Fuchs' protective kept well, and was regarded as effective for twenty years, but later tests showed that its chemical composition was materially changed, and that it no longer afforded security. It may be mentioned here that it was not then found available for scenery on account of the gloss it imparted. During this period the following mixtures came into vogue, chiefly for external protection, as in the case of shingled roofs: three parts of wood ashes and one part of boiled linseed oil; three parts of alum and one part of copperas; ashes and lime with skimmed milk as a binding material.

In 1841 Payne[8] introduced his combined process for rendering wood not only uninflammable, but also proof against wet and dry rot and insects. It consisted in the precipitation throughout the mass of a piece of timber, of barium or calcium sulfate by double decomposition. In carrying out the process, wood is introduced into a capacious cylinder, the air is drawn out by steam, a solution of barium or calcium sulfid is injected into the partial vacuum; the cylinder is exhausted again and then completely filled with the solution of the sulfid, pressure is increased to 140 pounds per square inch, and after an hour the solution is drawn off. The operation is then repeated, use being made of a solution of copperas; as a result the pores of the wood are largely filled with the insoluble sulfate and it becomes hard as stone. The soft, porous, cheaper grades of wood are thus rendered equal in point of durability and strength to the hardest varieties of timber. Wood prepared in this way is largely used in England in connection with public works and railways.

At about this period several processes were introduced for the preservation of wood against decay; and claims were made that these were also valuable for rendering wood uninflammable.[8] These processes consisted essentially in the introduction into the

pores of wood of metallic salts in solution, which combined with the nitrogenous matter present to form insoluble non-fermentable compounds, and therefore removed sources of decay.

The chief methods employed were kyanizing or impregnation with mercuric chlorid; burnettizing or impregnation with zinc chlorid, using a 3% solution; boucherizing or injection of copper sulfate, using a 1% solution; and Beer's process of impregnating with borax. All of these methods give partial protection against combustion. With regard to their availability, expense and the evolution of poisonous vapors when exposed to heat militate against the use of corrosive sublimate. Copper sulfate, which can be absorbed to the extent of 20 kilog. per cubic meter of wood, is far inferior to many other salts as a fire protective; it colors the wood blue when exposed to atmospheric conditions, and in common with the mercuric salt, corrodes iron nails and bolts. Zinc chlorid is more efficient although in common with the two preceding salts it affects the tenacity and elasticity of wood. Borax seems to be more free from the objectionable features just enumerated and more recent experiments have shown that its protective power is far superior to that of the copper or zinc salts, although inferior to that of sodium tungstate and ammoniacal salts.

The operation of impregnation in closed vessels by the use of a vacuum was devised by Samuel Bentham in 1794.[21] It was successfully employed in France by Breant and Bethel in 1830 and later in England for the purpose of kyanizing and burnettizing as well as in connection with Payne's process.[21] In boucherizing, the copper sulfate solution is usually forced longitudinally from the butt to the trunk of a tree, just after it is felled, by an ingenious arrangement, involving the use of rubber caps and an elevated tank.[8]

In 1855 Salomon's process[7] of treatment with aluminum sulfate and calcium chlorid, already described in connection with textile fabrics (p. 129) was applied to wood with some little success.

During this same year Maugham's process[7] of treating wood with a mixture of sodium phosphate and ammonium chlorid, and Jackson's process, based on the combined use of zinc and ammonium salts, were both submitted to critical tests by Sir Frederick Abel,[7] who found neither as cheap or as efficient as sodium silicate. Abel reported at length to the English Board of Ordnance on the advantages offered by the use of sodium silicate, which he had rec-

ommended at an earlier date for use in the Crimea to render huts fire-proof, and which was used in 1856 in camp huts at Aldershot for the Royal Engineers. By applying first a coat of silicate, then a coat of lime, and finally a second coat of silicate, Abel obtained a covering which resisted rain and showed no tendency to crack, shrink, or detach itself from the wood. The cost was one cent for five square feet. Later reports to the board made by Abel in 1870 and 1872 state that the efficiency of this protective was totally unaffected by time. In 1881 he also reports that sodium tungstate, already employed for fabrics, may be successfully used for wood, but that it offers no advantages over the sodium silicate process. It is absorbed by wood at the rate of 56 kilog. per cubic meter.

Patera, who studied the subject very extensively, recommended in 1871[4] the use of magnesium borate for wood, finding it fully equal to sodium tungstate. He urged also very strongly the use of a mixture of 1 part strong ammonia and 2 parts gypsum, especially for roofing. Severe tests applied to this protective yielded such satisfactory results that the Austrian Minister of Finance recommended it for all government buildings where woodwork was exposed. Patera also advises the use of a coating of 1 part of ammonium sulfate, 2 parts gypsum and 3 parts water. Another protective covering recommended by him is obtained by first coating wood twice with a saturated solution of 3 parts of alum and 1 part of copperas, and then applying a coat of clay mixed in copperas solution.

The successful use of sodium silicate led to the employment of various silicious paints. One devised by Vilde and Schambeck[20] seems to have given good results. Its composition is pulverized glass 20 parts, pulverized porcelain 20 parts, pulverized stone 20 parts, quicklime 10 parts, waterglass 30 parts. The thick syrup is applied with a brush and hardens quickly.

Ransome's silicious paint,[7] introduced in 1871, consisted of a mixture of pure quartz and waterglass. After application it was coated with calcium chlorid in order to render it perfectly insoluble. It has not been used of late years.

Another process involves the application of three coats of dilute waterglass, then of two coats of the same mixed with powdered glass; finally of one of thick waterglass.[13] Other preparations consist simply of more or less dilute waterglass, to which zinc oxid or ferric oxid has been added.[13] A most important modification

of the simple silicate is that known as cyanite[13] and prepared by introducing aluminum hydrate into waterglass; so that it is practically a basic silicate of aluminum. It is a perfectly colorless liquid, and is applied with a brush. The cyanite is manufactured in England, and is employed in the English War Department by the Woolwich Arsenal, and by the Department of Railroad Inspection. That the product is variable would be indicated by Helbig's analysis[15] in 1888 when he found nothing present but waterglass.

Among other recent preparations is the ignifuge of Martin[5] of France (1880) used for impregnation, and composed of ammonium chlorid 15 parts, boric acid 6 parts, borax 3 parts, water 100 parts.[13] Another French preparation is that of Vendt and Herard,[11] 1885, also for impregnation. It consists of alum 12 parts, borax 5 parts, sodium thiosulfate 3 parts, potassium sulfate 10 parts, water 70 parts. Somewhat peculiar are the following combinations also used in France;[21] the first a solution of lead sulfate in neutral tartrates; the second an ammoniacal solution of a mixture of calcium acetate and calcium chlorid. Brocher's preparation[13] manufactured near Dresden, and used to some extent in Germany, is of unknown composition, and involves the use of three different liquids in the course of the application of the several coats. Objection has been made to it for this reason, as well as on account of the tendency of the solutions to solidify.

The general recognition of the utility of protective coatings led gradually to the extended use of asbestos. E. G. Erichsen[7] of Copenhagen in 1881 devised a new protective which consisted of a soluble silicate, metallic oxids, and lime, with 10–20% of asbestos. It was applied with a trowel and formed a sort of fire-proof enamel which could be washed with water. Erichsen's preparation was extensively used in Europe, both on the continent and in England.

A further step forward was made in 1883 by C. J. Mountford[7] of Birmingham, England, who brought out a preparation which consisted of asbestos ground and reground in water, sodium or potassium aluminate and waterglass. When liable to exposure to atmospheric agencies, it receives further a certain amount of oil driers and gummy matters and sometimes zinc oxid or barium sulfate. The United Asbestos Co. of England has manufactured this product on a large scale for ten years, and it has been extensively employed, especially in England. Among other important edifices treated with it are the Parliament Buildings, the British

Museum, South Kensington Museum, the Crystal Palace, various theaters, Royal palaces, etc. The cost of this material is eighteen cents per kilog., and 100 kilogs. suffice to cover with three coats a surface of 54 square meters, so that the cost per square meter is about thirty-three cents. It is a thick, gray product easily applied, presents a satisfactory appearance when used alone on wood, and furnishes an excellent basis for the application of other paints.[13]

This represents probably the best type of protective coating, thus far devised. There are also two other English preparations of some repute, the nature of which is apparently analogous to the above: Bell's asbestos paint and Blane's fire-proof and water-proof paint;[13] while, in America, a single firm manufactures an asbestos paint.

Such is the history of the different methods of restricting the combustion of wood which have been presented during this century.

Let us next note the means devised to test comparatively the value of the diverse materials recommended.

TESTS FOR FIRE-PROOF PREPARATIONS.

In Versmann and Oppenheim's extended investigation on protectives for textiles,[2] the study was carried on in such a way as effectually to eliminate one after another of the salts experimented upon until a small group was left, the efficiency of each member of which, under varying conditions, was satisfactorily demonstrated. The usefulness of impregnation by sodium tungstate is illustrated to you by exposure to a flame of strips of cotton cloth, some of which have been soaked in a tungstate solution, while others are in the ordinary condition. The merits of the different protectives for wood, as each one in turn came before the public, until a recent date were usually tested by application to a small hut or the like, within which an active fire of very combustible material was started. Such was the custom of Sir Frederick Abel[7] in his series of experiments already referred to.

Some thirty years ago Professor Pepper, of London, made comparative tests on four salts, strongly recommended for impregnating wood, and as a result placed them in the following order, the most efficient first:[20]

1. Ammonium phosphate.
2. Sodium tungstate.
3. Borax.
4. Alum.

The most thorough and valuable study in this field was made in 1887 by two Belgian chemists, Professors Boudin and Donny, of the University of Gand (Ghent) at the request of the Belgian Minister of Public Works.[13] They submitted to rigorous comparative tests all of the preparations then in vogue, some nineteen in number, and it is to be regretted that their exhaustive report has not been reproduced *in toto* in our journals.

P. Lochtin[17] in 1893 introduced a simple and easy if not perfectly exact method of testing, which he applied to about fifty chemical compounds and brought out several interesting facts.

We will consider first his more elementary methods, taking up later the more improved ones of Boudin and Donny.

Lochtin used strips of thick filter paper 50 cm. long and 5 cm. broad which are soaked in solutions of the substances submitted to experiment, usually a series for each substance of 0.5, 1, 2, 3.5, 5, 10, 15 and 20% solutions of the anhydrous compound. After being hung on lines and drying at ordinary temperature, the lower ends where greater quantities accumulate are clipped off. When insoluble precipitates are to be obtained in the paper, it is first soaked in a solution of the soluble salt; then dried; then soaked in a solution of the precipitating reagent, dried, washed, soaked for 6–12 hours in water; washed and finally dried. The strips are then folded lengthwise and while held horizontally, with the folds beneath, kindled at one end. Observation then shows whether the foreign substance hinders or helps combustion, and what is the mimimal relative weight of a salt or the mimimal strength of its solution, necessary to render the paper uninflammable.[19]

Experiment indicates that different substances, although in solutions of equal strength, are retained unequally by the paper; the amount retained increasing in proportion to the insolubility or ease of crystallization of a compound. Very soluble substances are absorbed in almost equal proportions. It is also worthy of note that apart from compounds which are practically storehouses of oxygen, as the chlorates, there are substances which distinctly favor combustion, the alkaline sulfates for example. As illustrations of Lochtin's method: a strip soaked in a 20% solution of Na_2SO_4 is kindled at one end. It is observed that it burns easily and readily to the end, as readily as if no foreign matter were present. Again, four strips of paper soaked in ammonium chlorid solutions; *a* in a

20% solution, *b* in a 5% solution, *c* in a 2% solution, and *d* in a 1% solution, are in turn held in the flame. No propagation of flame is shown by *a*; *b* shows a small flame which is extinguished quickly on removal from the source of heat; *c* yields a larger flame which burns for about 5 cm. after removal; and *d* furnishes a still larger flame, which burns to the end. It is evident that the use of a 2% solution affords partial protection, and of a 5% solution, full protection against inflammability. I have found in personal experience an advantage in using for elementary tests the thin slips of pine wood about 8 cm. long and 1 cm. wide, easily obtained from any tobacconist. These are preferable to Lochtin's strips, as they can be used for testing protective coverings as well as solutions; and in the case of the latter the distribution of the foreign substance throughout the strip is more uniform. The experiments conducted before you illustrate the relative resistance imparted by a number of the preparations already enumerated.

A third method of comparative testing was devised by Boudin and Donny.[13] A cylinder of light iron rods 40 cm. long and 25 cm. in diameter is mounted upon an horizontal axis so that it can be easily kept in rotation. Beneath this cylinder is a series of five Bunsen burners, consuming 1000 liters of gas hourly. The wood used for the experiments is in the form of rectangular sticks 39 cm. long and 15 mm. square. After treatment by injection or painting, bundles of four sticks of each preparation—the individual sticks kept apart by light wedges—are attached by wire to the rods of the cylinder, parallel to its axis, and at equal distances from each other. A bundle of sticks which have not been treated serves as point of comparison in each charge of the cylinder. The row of lamps is next lighted, and the cylinder turned at the rate of six revolutions per minute, so that all of the bundles are uniformly and evenly exposed to the action of the flame. The time is then noted at which each bundle takes fire, or is seriously affected by the heat; and when the combustion of a bundle becomes sufficiently active to affect its neighbors, it is removed. As an example of the working of this method the following series of tests may be quoted from the Belgian report:

Wood not treated took fire at the end of $1\frac{3}{4}$ minutes.

Wood treated with zinc sulfate or alum, at the end of $3\frac{1}{2}$ minutes.

Wood treated with ammonium sulfate or copper sulfate at the end of 5 minutes.

Wood treated with borax, or boric acid, or Martin's ignifuge, or Brocher's preparation, at the end of 8 minutes.

Wood treated with sodium tungstate, at the end of 10 minutes.

Wood treated with calcium chlorid or ammonium chlorid, at the end of 15 minutes.

Wood treated with waterglass alone, or with lime, or with powdered glass and kaolin, or cyanite, or the Bell, Blane or United Asbestos Co. preparations, or ammonium phosphate, at the end of 30–40 minutes.

The two latter were charred throughout without the production of flame.

A still more rigorous and decisive test has been devised by Boudin and Donny,[13] one which places the experimenter as nearly as possible in the conditions which ordinarily precede the outburst of a conflagration, viz., the production of a flame of greater or less intensity in immediate contact with inflammable material; such as happens when an oil lamp is overturned, a box of matches is kindled by the gnawing of an inquisitive rat, or the like.

The test is simple in its nature, and depends as in the preceding method upon the use of wooden rods subjected to a protective treatment. A convenient size is that of 20 cm. in length and 15 mm. square. Thirty-six rods of the same preparation are used to form a small open construction by simply superimposing rows of six alternately crossed upon each other, leaving in the center an open space about 6 cm. wide for the reception of burning material. The whole arrangement is one permitting of the freest possible circulation of air, a condition which is further aided by placing the construction upon a piece of heavy wire gauze supported upon two bricks. Little bundles of splints weighing 35 grains each are used as sources of combustion. They are introduced into the central space, lighted, and the result carefully noted. If combustion is not communicated to the construction by the burning of a single charge, a second is added and so on. It is easily seen from the series of experiments with these constructions carried on before you, that this method of the two Belgian chemists is of the most searching and exacting nature, and yields comparative results of the highest value.

In such a series of tests, for example, a construction of ordinary wood takes fire at the end of one minute, is in complete combustion two minutes later, and at the end of ten minutes leaves a mass of

ashes. Wood treated with ammonium chlorid takes fire at the end of three minutes and undergoes complete combustion. Wood covered with cyanite takes fire at the end of three minutes and burns slowly for fifteen minutes, leaving the exterior intact. Wood treated with three coats of waterglass stands exposure to four successive charges of combustible, with but little evidence of the propagation of fire; although the surface of the rods is deeply altered by the exudation and swelling of the silicate. Wood treated with ammonium phosphate, or the United Asbestos Co. preparation, is scarcely affected after four successive charges. The construction remains intact with the interior slightly charred.

RESULTS THUS FAR ATTAINED.

Leaving the methods of testing, let us now briefly summarize the results of experiment, and experience with fire protectives up to the present date. For textile fabrics, sodium tungstate and magnesium borate yield unquestionably the best results, when materials are to be ironed; while ammonium phosphate or sulfate is preferably used in other cases.[6]

The use of the tungstate, especially, is widespread in England. It may be of interest to know that in the laundry of the Queen's Palace, all fabrics of vegetable origin are treated with a solution of neutral sodium tungstate of 28° Tw. containing 3% of Na_2HPO_4. This solution is added to the starch also when the latter is employed.

Abel's researches[7] show that in naval warfare, calcium chlorid is valuable to protect rope mantelets, while canvas is well protected by stannic oxid; and still better by the double silicate of sodium and lead.

The efficacy of sodium tungstate, as well as of the ammonium salts, for the scenery and decoration of theatres, has also been firmly established.

The comparative results of Lochtin's experiments on pure cellulose[19] may well be summarized here as they offer a valuable classification and furnish useful hints; although it must not be forgotten that the tests were elementary in their nature, and the conclusions hence open to criticism, as is in some cases evident.

Lochtin divides compounds into three classes, with reference to the effects on combustibles. (1) The *antipyrenes*, which render cellulose unimflammable, when present in relatively small amounts, and when used in weak solutions. (2) *Indifferent substances* which

are effective only when present in large amounts. (3) *Substances which favor combustion.*

I. Antipyrenes.

Quantities of anhydrous substances required to render cellulose uninflammable.

	Minimal strength of solution used in %	Minimal relative weight (cellulose =100)
NH_4Cl	1.5	4.2
$(NH_4)_2HPO_4$	1.5	4.5
$(NH_4)_2SO_4$	1.5	4.5
$ZnCl_2$	1.5	4
$CaCl_2$	1.5	4.5
$MgCl_2$	1.5	4.5
$Al_2(OH)_6$	1.5	3.8
$KAl(SO_4)_2$	2	—
$ZnSO_4$	1.5	4.5
$SnCl_2$	2.5	—
$Na_2B_4O_7$	1.5	8.5
B_2O_3	2.5	10

II. Indifferent Substances.

HKO	7.5	—
$MgSO_4$	7.5	15
$NaCl$	7.5	35
Na_2SiO_3	17.5	50
SiO_2	12.5	30
KCl	20	45
Na_2HPO_4	7.5	30
K_2HPO_4	20	—
$Al_2\,3(B_4O_7)$	12.5	24
$AlPO_4$	10	30
$Ca_3\,2(PO_4)$	12.5	30
$Mg\,HPO_4$	12.5	30
$Zn\,B_4O_7$	7.5	20
$ZnHPO_4$	15+	—
WO_3	10+	15+
Na_2WO_4	10+	15+
$(NH_4)_2WO_4$	7.5	10+
Clay (air dry)	—	75
$NaC_2H_3O_2$ and $KC_2H_3O_2$	7.5—5	—

III. Substances favoring Combustion.

Na_2SO_4, Na_2SO_3, Na_2SiO_3, Na_2CO_3, Na_2SnO_3, $Mg(OH)_2$, K_2SO_4, $ZnCO_3$, $CaCO_3$, $MgCO_3$, $CaSO_4$, $FeSO_4$.

In reviewing the above tables, it is of importance to note that the aluminum hydrate used is that obtained by double decomposition between sodium aluminate and sodium bicarbonate. The product formed by the action of ammonia on aluminum sulfate is of no value. It will be seen, also, that the somewhat expensive sodium tungstate is much less effective than many other compounds, the chemical nature of which debars them, however, from ordinary application. Thus (apart from cost), acid or alkaline reaction, difficulty in solution, hygroscopic properties, or readiness to decompose on contact with hot iron or otherwise, handicap as it were most of the antipyrenes. The chief value of Lochtin's work is to be found in the recognition of aluminum hydrate as so pronounced an antipyrene and the fixing of the conditions under which it is deposited in the most effective form.

The most important and decisive results with regard to the efficiency of the different current protectives of wood are furnished by Boudin and Donny.[13] Using a classification based upon their rigorous and conclusive tests, we can arrange the protectives in the following series, ascending from the least effective to the most effective.

I. Preparations of little value.

1. Injection of sodium tungstate (56 k. per m^3.)
2. " copper sulfate 20 "
3. " calcium chlorid 50 "
4. " ammonium chlorid 48 "
5. Coating of waterglass (43% solid residue), 1 coat, 286 gr. per m^2.
6. Coating of waterglass and zinc oxid, 4 coats, 1 kilog. per m^2.
7. " Martin's ignifuge, No. 4, 2 coats, 450 gr. "
8. " Brocher's preparation, 3 "
9. " Blane's asbestos paint, 2 " 1 kilog. "
10. " cyanite (basic aluminum silicate), 2 coats, 450 gr. per m^2.

II. Preparations of some value which lessen in a marked degree the Inflammability of Wood.

11. Covering of cyanite, 3 coats, 570 gr. per m^2.
12. " Bell's asbestos paint, 3 coats, 820 gr. per m^2.
13. " waterglass* and ferric oxid, 4 coats, 700 gr. per m^2
14. " waterglass* and powdered glass, 6 coats, 900 gr. per m^2.
15. Covering of waterglass* (undiluted),† 3 coats, 475 gr. per m^2.

III. Preparations of the highest efficiency which prevent almost entirely the Propagation of Fire in Wood.

16. Covering of the United Asbestos Co. Paint (waterglass, sodium aluminate and asbestos), 3 coats, 850 gr. per m^2.
17. Injection of ammonium phosphate, absorption of 75 kil. per m^3 after boiling for twelve hours in a 16% solution of the salt.

These two protectives would seem therefore the high-water mark of what chemists have attained in their efforts to render wood uninflammable. With regard to the permanence of their protective power, it has been observed that, after the lapse of two years, wood treated with the asbestos preparation had lost in no measure its resistant qualities; while that injected with ammonium phosphate showed an exceedingly slight diminution in the efficiency. No diminution was noticed at the end of nine months in the resistance of injected wood, kept at ordinary temperature, or at 45° C. or covered with a coat of oil paint. It should be noted also that the solution of ammonium phosphate does not affect nails and other objects in iron even after contact for several months; also that the solutions of the salt must be nearly saturated in order to yield satisfactory results.

Boudin and Donny's experiments would tend to indicate a slight

* In all these tests a waterglass of 43% solid residue was used. It was generally diluted with water; but this additional water is not included in the weight per m^2.

† Wood when first covered with waterglass presents a varnished appearance. This is not retained long, as the coating soon begins to scale, and the surface is covered with a white efflorescence.

lessening in the strength of wood which has been injected. The general conclusions drawn from their investigations are:

1. The incombustibility of wood, *i. e.*, its non-alteration when under the influence of heat, cannot be attained. It is possible, however, to secure its non-inflammability, so as to preserve ordinarily any structure exposed to an accidental fire, or at least to allow time for the arrival of the ordinary extinguishing appliances, unless it be filled with combustible material.

2. Of the preservative processes used, injection of saline solutions or the application of protective coverings, the former would seem ill adapted for timber of large dimensions, but of manifest value for the less bulky forms of wood. In all such cases the use of ammonium phosphate in saturated solution offers such incontestable advantages, that despite its high price, it should be employed unless excluded absolutely by limitations of expense. (Ammonium phosphate can be obtained for about $50 per 100 kilos., and as a cubic meter of wood absorbs 75 kilos., the cost per cubic meter would be about $38.)

3. In the majority of cases protective coatings are preferable. The most efficacious is that containing sodium aluminate and asbestos in waterglass; while waterglass alone, or with the addition of aluminum hydrate, is of great value.

EXPLANATION OF THE ACTION OF PROTECTIVES.

Such being the practical results attained, it is of interest for us next to know in just what way these chemical compounds act to prevent inflammability. It is in fact a matter of surprise that the experimentation in this field has been so largely empirical, neither preceded nor followed by theoretical considerations.

In studying the effects of heat on ordinary wood the following will be noted.[6, 13] When exposed for some time to a temperature of 200° C., wood becomes light brown and its strength is materially affected. At 300° it is charred completely, losing all power of resistance, but still without a trace of flame. If, however, the wood be in contact with flame, or be exposed to a red heat, change takes place rapidly, and if air have free access it bursts into flame, and combustion does not cease until the entire mass is reduced to ashes.

When wood protected by a suitable coating, such as waterglass, is exposed to a temperature of 200° C., it acts exactly as ordinary

wood. Wood, however, which has been injected with saline solutions, as ammonium phosphate, is more liable to change. It assumes a deep brown tint, and the resistance to strain is greatly lessened. At 300° all forms of protected wood are carbonized, exactly as the ordinary wood, and without flame.

At a red heat, or in contact with flame, prepared wood is completely destroyed; but there is a vast difference between the rate of destruction and that of non-protected wood. At first there is a pronounced period of direct resistance. In cases where external applications have been made, the heat gradually penetrates the protective coating, jets of gas issue through fissures in it, and their combustion contributes to the intensity of the surrounding sources of heat, until finally combustion is complete. In the case of wood impregnated with suitable saline solutions, resistance to the flame is likewise marked, but much gas is evolved. This gas is not inflammable but seems on the contrary to interfere seriously with the combustion of the surrounding fire. Complete charring is finally reached. It is evident in both cases that the ordinary effects of heat upon wood are seriously hindered or retarded. The first effect of heat, as we have seen, is to produce gas and leave carbon. This gas, if allowed to burn with the oxygen of the air, furnishes a fresh supply of heat to bring about further evolution of gas. But as organic matter and the resultant charcoal are both poor conductors of heat, gasification would proceed very slowly unless the coal on the surface also changed to gas by burning with atmospheric oxygen (as well as by reducing the CO_2 and H_2O present) thereby increasing the available temperature. The maintenance of a sufficiently high surrounding temperature must eventually cause the penetration of enough heat into the body of wood exposed to produce complete gasification and carbonization, and finally complete combustion of the charcoal. This action can be retarded evidently by two distinct agencies. The first is the evolution of an inert or non-combustible gas or vapor from the wood through the influence of heat; the second is the presence of an external coating, which is not only a poor conductor of heat, but also protects the outside zone of charcoal from contact with atmospheric oxygen. It is in one or both directions that fire protectives render service.

The ammonium salts are good types of the first class. Ammonium chlorid and ammonium sulfate are readily vaporized and dis-

sociate, the first into NH_3 and HCl, the second into NH_3,N,H_2O $(NH_4)_2$ SO_3 etc. Ammonium phosphate decomposes slowly to metaphosphoric acid (62% of its weight) NH_3 and N_2O. It is probably this slowness of decomposition which renders the phosphate superior to the other ammonium salts. In the case of Mg Cl_2, $ZnCl_2$, etc., HCl is driven off. In the case of other salts, such as the alums, the borates, copper sulfate and sodium tungstate, large amounts of water of crystallization are necessarily liberated in the form of aqueous vapor. It is a matter of surprise that this fact, that the storage of considerable amounts of water in the solid form in the interior of wood is a potent factor in the protective value of a number of antipyrenes, should have escaped the attention of chemists. It is an easy matter to calculate the volume of aqueous vapor capable of being formed from a given weight of $Na_2B_4O_7 + 10H_2O$ or $Na_2W_4O_{13} + 10H_2O$ or $K_2Al_2(SO_4)_4 + 24H_2O$. There is no question but that such salts as the above retard the attack of flame chiefly through this agency at first, although after the expulsion of the water of crystallization, the presence of the saline substance coating the charred surface and acting as a poor conductor of heat, as well as preventing the access of oxygen, continues the protection for a certain time. It is in the varying ability of different compounds to form coherent, continuous protective coatings after exposure to heat that we find the reason of the superiority of one composition, for external application, over another. Thus waterglass alone gives good results. When wood treated with it is heated, we notice a puffing out and swelling, a certain amount of vapor escapes, and the residue is left as a light, voluminous, fairly coherent covering, through which air can penetrate but slowly to the charred surface beneath, and heat is likewise conducted but slowly. The addition of aluminum hydrate to the waterglass seems to increase the resistant properties of this envelope, while the further addition of asbestos and the substitution of sodium aluminate for aluminum hydrate, forming thereby practically a quadruple silicate of sodium, magnesium, calcium and aluminum, give the highest resistant power.

It may be pertinently inquired, why does the presence of some salts seem apparently to help combustion? Lochtin explains this action[19] by the uneven distribution of some substances during drying or precipitation; more, proportionately, remaining on the surface of the paper or wood used. Here they form porous but slightly

compact crusts; and these favor continued glowing or combustion by preventing a loss of heat.

PRACTICAL APPLICATION OF THE KNOWLEDGE GAINED.

With this exposition of the results attained in the contest with fire—the fruit almost exclusively of the work of European chemists—what should be the practical application of the knowledge gained to our own conditions in America? In the first place there should be a rigorous insistence on the use of protective agencies for *all* wood employed in buildings containing material of permanent value, such as deposits of archives, museums, libraries, etc. Many such structures, while built essentially of stone, brick and iron, have wooden floors, shelves, cases, doors and other furnishings. Perhaps in no case should this rule be carried out more strictly than in the light structures erected for exhibition purposes, where frequently large numbers of articles, unique in their nature, are gathered together. The frequent object lessons in connection with the Chicago Exposition, and the ghastly irony of the destruction by fire of the building of the Berlin Exhibition of safety appliances a dozen years ago, should not be without effect.

Next, all buildings wherein large assemblages are held should receive thorough protection. The studies made by special committees on theater protection, in London and Philadelphia, show clearly how easy it is to assure almost absolute safety. Curtains, scenery, decorations and woodwork generally can be as easily and economically rendered non-inflammable here, as in the great cities of Europe, where a few sharp lessons early led to the adoption of proper safeguards. The recent disaster in this very city of Brooklyn shows vividly the extent of danger to which we are exposed in our churches, and emphasizes the necessity of using the proper protective agencies in their construction. The same desirability of using uninflammable wood for the construction of the stands about our ball-grounds and other out-of-door places of amusement has been most strikingly shown in three of our great cities during the past month. Above all, the edifices of our institutions of learning should be blameless in this regard. The destruction of the stately pile of Toronto University, and the fire-swept campus at Madison should be the last instances in our land where all the precious memories clinging about an alma mater fall prey to relentless flame. Nowhere are the terrors of fire greater than in

connection with water transportation, even in these days of iron built craft. Our travelling public, which is practically the whole people, has the right to insist on the most extended use of fire protectives on all woodwork of our steamers for river and ocean navigation. The same protection should be extended to railway cars, for even since the abolition of the car stove it is evident that the factor of fire must frequently be added to the dangers of wrecks.

The applications enumerated above are nearly all easily within the reach of legislative enactment, as they affect the interests or lives of the public.

It is earnestly to be hoped that governmental initiative may be awakened to utilize the experience of other nations, render all public buildings models of security against fire as well as require compliance with a few simple regulations on the part of all ministering to the wants of the masses of the people.

How far the use of protective agents may be introduced into ordinary construction, and into household equipment it is difficult to say.[6] In England the custom of protecting wearing apparel of vegetable fiber is widespread. No reason exists why American women, earnest in reform, should not advocate a similar custom here. There is no question, however, but that great stress should be laid upon the wisdom of impregnating the curtains, draperies, and hangings of our homes. These are of necessity peculiarly exposed to danger through either carelessness or accident, and have been the starting point for many disastrous fires.

In considering the question of building, there is also no doubt but that the safety of edifices erected in accordance with the principles of slow burning construction, already mentioned, could vastly be augmented at slight outlay by the application to all exposed wood surface of the composite silicates.

It is to be hoped that the slow burning principle may soon be extended to domestic architecture, but even with our present methods, it is easily possible with the outlay of a few per cent on the cost of the house to lessen enormously its fire risk. All beams, joists, studding, etc., which are later to be hidden, can be coated during the process of erection. Silicious coatings can also be applied to all surfaces outside and inside which are ultimately to be painted. Finally, woods to be used for interior finish can be protected by steeping in a solution, preferably of ammonium phosphate,

if not, of one of the cheaper antipyrenes, before being varnished. Such a house, if isolated, and presupposing the use of wire lath, is practically fireproof in nineteen out of twenty cases of ordinary conflagration. If provided with brick walls and slate roof, the risk is greatly lessened, and it is not difficult to recognize that blocks or districts of such construction are free from *all* danger of conflagration; that, in fact, fire will be confined exclusively to such rooms or houses as may be used for the storage of combustible material. Insurance, under such conditions, approaches almost the vanishing point; and the freedom of apprehension from loss by fire is not to be measured by dollars and cents. We are here entering upon the proper province of another science. The chemist has provided the means of coping successfully with the dangers of combustion. It is for the economist to insist on the utilization of his achievements, in assuring increased comfort and security to society. Suffice it only to add that existing structures may to a great extent be protected especially for those few precious minutes between the discovery of a fire, and the arrival of aid, by the generous application of the silicious compositions to all exposed woodwork. The direct value of such treatment has been promptly recognized in England by a decrease of 50% in the insurance rates on houses so treated.

FIELD FOR FURTHER INVESTIGATION.

Finally, what remains for the chemist to do in this field? Indirectly he may accomplish much in lessening the fire risk. First in the study of illuminants. Whatever tends to displace the use of petroleum for domestic lighting tends by so much to diminish the national fire bill, as this one substance is a most prolific cause of conflagration. It is to be hoped that the way may be opened to an economical and convenient use in this connection of our vegetable oils, now so abundant; or to the introduction of a fuel gas saturated with hydrocarbons, so safe and economical that it may be promptly accepted for domestic lighting. Next there is little doubt but that the early approach of the era of cheap aluminum will effect an important revolution in the use of structural materials, the light, unchangeable metal tending to displace wood in many of its external and internal applications. In this field American chemists have taken the lead.

With regard to the production of new protectives it is hardly

probable that the last word has been said. We have seen how experiment, beginning with sodium silicate, led successively to the addition of aluminum hydrate, of lime, of lead salts, of powdered glass, and of finely divided asbestos to the convenient syrupy medium. There is but little doubt that other combinations, less expensive or more effective than those now in vogue, await the experimenter.

The high rank of aluminum hydrate among protectives as shown by Lochtin should lead to extended research with regard to its availability under different conditions, and its most economical application.

The utility of magnesium borate, so warmly recommended by Patera and Fischer, should be definitely established by comparative tests. It is not unlikely that combinations of the borates and silicates may also be found to render good service. Experiments on the deposition of insoluble tungstate in fabrics are also worthy of being carried out.

With regard to protection by impregnation it is doubtful whether any better agency than ammonium phosphate can be found. It would, however, be advisable to study the economical production of this salt for the purpose in question. Might it not be possible to attain cheapness by using successive baths of ammonium sulfate and sodium phosphate; or could not acid calcium phosphate be brought advantageously into the reaction?

A further field of investigation is the possible combination of injection and repainting; impregnation with such deliquescent chlorids, as zinc chlorid or magnesium chlorid, being followed by a simple external coat of a silicious paint. Then the most favorable time for injecting or steeping wood with saline solutions should be definitely ascertained. Is it after completed seasoning, or when the wood is perfectly green, as advocated by Jones?

The question of the most economical combination of protection against fire and of preservation from decay and insect attack remains also to be settled.[8] Another important phase is the highest attainable efficiency, from the use of salts which store up in wood considerable amounts of water of crystallization, such as gypsum; for it must be borne in mind that every volume of solid water of crystallization yields 1700 volumes of aqueous vapor at 100° C.

It is largely along these lines that we may expect to see advance made in the province whose survey we now complete.

In conclusion, let me express the earnest hope that individually and collectively the influence of this Association may be helpfully thrown in favor of any general effort to lessen our tribute to fire. We have made ourselves felt in movements to combat the twin although antithetic evils of drought and flood by the preservation and extension of our forests, as well as in other economic directions. Can we not do the same in availing ourselves of the work of Gay Lussac, Fuchs, Versmann, Oppenheim, Abel, Tessier, Patera, and other chemists, by bringing into the American home and the American community that peaceful security and liberation from a dreaded tax, which comes with the practical abolition of danger from conflagration?

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PAPERS READ.

A NEW FORMULA FOR SPECIFIC AND MOLECULAR REFRACTION. By W. F. EDWARDS, Ann Arbor, Mich.

[ABSTRACT.]

SINCE Biot and Arago in the year 1806 undertook the verification of the Newton-Laplace formula, $(m-1)/d=k$ (a constant), much has been done and written on the relation of the index of refraction and density of a substance.

Gladstone and Dale (Phil. Trans., 1858) while trying to verify the Newton-Laplace law when applied to liquids found that $(m-1)/d=k$ was much more nearly in accord with their experiments. Landolt, studying the relation of the numbers obtained by multiplying the Gladstone formula by the molecular weight of the substance, found that the molecular refraction, as the numbers thus found were designated, is the sum of the atomic refractions of the elements of which it is composed. Later Bruehl found that when carbon is united ethylene-wise the molecular refraction is greater than the sum of the atomic refractions of the elements composing the substance. Landolt also applied this empirical formula to mixtures and was able to determine the per cent of each, when there were but two components, by optical analysis.

In the decade between 1880 and 1890 two theoretical demonstrations of Gladstone's formula were furnished (Dufet, 1885 and Sutherland, 1889) and two new formulæ were introduced (that of Lorentz and Lorenz and that of Ketteler) giving new stimulus to a line of work in which already much had been done. None of these have proved to be entirely in accord with all known facts. It is to be said, however, that the formula of Ketteler has not been the subject of much experimental verification.

The formula which I now offer has at least the merit of simplicity of demonstration. It asks no question as to the size and shape of molecules, but simply assumes that light is transmitted faster *in vacuo* than elsewhere and that the diminution of the rate depends on the amount and kind of material in unit volume and on its physical state.

Taking the well-known equation for the index of refraction,

$$M=\sin I/\sin R=V/V_1,$$

where V is the velocity of light in the ether of space and V_1 is the velocity in the substance, if we call the difference between V and V_1 A, we have

$$MV-MA=V, \quad \text{or} \quad (M-1)V/M=A.$$

If the difference, A, is proportional to the amount of substance in unit volume, and we assume as the unit one gram of substance in one cubic centimeter, and that X is the retardation of velocity for a unit substance, then

$$X = (M - 1)\ V / M\ D,$$

where M is the index of refraction and D is the specific gravity of the substance.

If there are several substances in a mixture for which

$$(M - 1)\ V / M\ D = C,$$

C being the retardation of V by the mixture, and

$$(m - 1)\ V / m\ d = a, \quad (m_1 - 1)\ V / m_1 d_1 = b, \quad (m_2 - 1)\ V / m_2 d_2 = c,$$

etc., are the corresponding equations for the components, then

$$C = p\ a + p_1 b + p_2 c + \text{etc.}$$

where $p + p_1 + p_2 + \text{etc.} = 1$, and represent the per cent of the components in the mixture. Since V is a factor of both members of the equation, the equation may be written in the form

$$(M - 1) / M\ D = p\ (m - 1) / m\ d + p_1 (m_1 - 1) / m_1 d_1 + p_2 (m_2 - 1) / m_2 d_2 + \text{etc.}$$

Table I. shows that $(M - 1) / M\ D$ increases slightly as the temperature increases until the change to the vapor state, when it suddenly increases from one fourth to one third of itself. A future paper will deal with this change and the probable cause of it.

Table II. shows that the difference between the two members of the equation $(M - 1) / M\ D = p\ (m - 1) / m\ d + p_1 (m_1 - 1) / m_1 d_1$ for mixtures of two components is usually in the fourth decimal place.

Table III. shows in the numbers representing the molecular refraction $P\ (M - 1) / M\ D$,

an average difference of 5.11 for the hydrocarbons
" " 5.33 " alcohols
" " 5.24 " aldehydes
" " 5.28 " acids
" " 5.33 " iodids
" " 5.31 " ethereal salts for each increase of CH_2 in the formula of the compound. This gives a general average difference of 5.27 for all the compounds considered, and is very close to the greater number of the differences for the hydrocarbons, although the average for them was only 5.11. The average difference for CH_2 in the aromatic compounds is 5.24.

Landolt, using the Lorenz-Lorentz formula, found an average difference for CH_2 of 4.61 for the alcohols, 4.57 for the aldehydes, 4.56 for the acids, and 4.48 for the ethereal salts of Table III. The average difference for the four groups is 4.56, and for corresponding groups in Table III. it is 5.29. The difference between the highest and lowest average difference is 0.13, which is 2.85 per cent of 4.56. The difference between the highest and lowest average of corresponding groups

in Table III. is 0.09, which is only 1.69 per cent of 5.29. My formula shows a less percentage error than the Lorenz-Lorentz formula, which Bruehl has shown to give a less percentage error than the Gladstone formula.

If the numbers for the molecular refraction of the ethereal salts be compared with the corresponding numbers for the acids, it will be found that the difference for CH_2 is higher than is found otherwise in the table. For example methyl-acetate, methyl butyrate, and methyl valerate give the numbers respectively 21.63, 31.75, and 37.20, while the corresponding acids give the numbers 15.44, 25.99 and 31.45, the difference between the numbers for the salt and the acid being respectively 6.19, 5.76, and 5.65, an average of 5.86.

Table IV. shows that the molecular refractions of the isomers agree very closely, the difference always being greater when an ethereal salt is compared with another substance not an ethereal salt.

In a future paper I purpose giving much more detail of the application of this formula to chemical problems. In this paper, which I consider as a preliminary notice of the formula, I have given tables sufficiently full to show that the formula and experimental evidence are concordant to a sufficient degree to warrant further work in this direction.

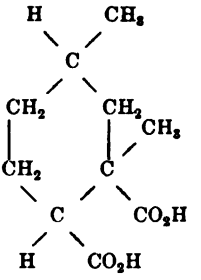
[This Paper will be printed in the American Chemical Journal.]

CAMPHORIC ACID. By Prof. W. A. NOYES, Rose Polytechnic Institute, Terre Haute, Ind.

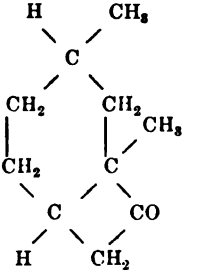
[ABSTRACT.]

IN a paper recently published[1] I have described the preparation of di-hydro-amino-campholytic acid, $C_8H_{14} < \begin{matrix} CO_2H \\ NH_2 \end{matrix}$, from β-camphoraminic acid. An isomeric acid, called amino-lauronic acid, has now been prepared from α-camphoraminic acid. Di-hydro-amino-campholytic acid when treated with nitrous acid gives the campholytic acid of Walker.[2] Amino-lauronic acid gives in the same way an isomeric unsaturated acid, closely resembling the lauronolic acid of Fittig and Woringer,[3] but the identity has not been fully established. There is also formed a lactone and a hydrocarbon, probably tetrahydroxylene. It has been shown, further, that the camphoraminic acid of Claissen and Manasse[4] yields amino-lauronic acid and not dihydroamino-campholytic acid when treated with sodium hypobromite. This proves that the methylene group of camphor corresponds to the carboxyamido group of α-camphoraminic-acid, and also to the carboxyl group of campholytic acid. The facts which have been established do not agree well with the tetramethylene formula for camphoric acid, but are consistent with the formula proposed by Collie,[5] and also with a similar formula,

[1] Am. Chem. Jour., XVI. 307.
[2] Jr. Chem. Soc. (London), 1893, 499.
[3] Ann. d. Chem. (Liebig), CCXXVII. 7.
[4] Ibid., CCLXXIV. 81.
[5] Ber. d. Chem. Ges., XXV. 1116.



This formula corresponds to Armstrong's formula for camphor,[1]



and is more consistent with the ready formation of cymene from the latter body. This formula has also been advocated by Wallech.[2]

Walker, who first prepared campholytic acid, and Hoogewerf and Van Dorp, who have prepared amino-lauronic acid, but have not published anything on the subject, have kindly left the further study of these bodies to me.

[This paper will be printed in the American Chemical Journal.]

MIXED DOUBLE HALIDES OF ANTIMONY AND POTASSIUM. By Prof. CHARLES H. HERTY, University of Georgia, Athens, Ga.

[ABSTRACT.]

ATKINSON, in 1883, endeavored to prepare two isomeric compounds, $SbCl_3$, 3 KBr and $SbBr_3$, 3 KCl by mixing the salts in the proportions indicated in the formulas. The same salt was obtained in each case. To this he ascribes the formula $K_3SbBr_3Cl_3$, $1\frac{1}{2}$ H_2O. The present investigation has for its object the determination of the character of this compound, whether it be a true salt or a mixture. From the results there is little doubt that it is a mixture. Compounds were prepared from solutions made up of $SbCl_3$ and 3 KBr in the proportions indicated in the formula, varying quantities of these being replaced by equivalent quantities of $SbBr_3$ and KCl. Analyses of these com-

[1] Ber. d. Chem. Ges., XVI. 2260. [2] Ibid., XIX. 921.

pounds showed variations corresponding to the variations in the composition of the solutions from which they were formed. It was expected that these compounds would prove to be mixtures of K_2SbCl_5, and K_2SbBr_5, but calculations based upon analytical results showed this to be wrong. To gain further knowledge of their character, salts were prepared from solutions made up of $SbCl_3$ and 3 KCl; and $SbBr_3$ and 3 KBr. The salts thus obtained are $K_{22}Sb_{10}Cl_{53}$ and $K_{22}Sb_{10}Br_{53}$.

Assuming the above series to be mixtures of these two, the calculated and analytical results are found to closely agree. Atkinson's statement that all antimony salts could be driven out of these compounds at 300°, leaving potassium bromid and chlorid, is not accurate, for it has been found impossible to remove all traces of antimony. The analyses of the potassium residues do not give very satisfactory evidence of any kind, but in a rough way they tend to confirm the view that the compounds are mixtures.

H. L. Wells has recently suggested that certain compounds which I considered mixtures of $KPbI_3$, $KPbBr_3$ and $PbBr_2$ are really mixtures of KPb_2Br_5 and KPb_2I_5. Though both views agree closely with analytical results, Wells' view is more probably correct.

[This paper will be printed in the American Chemical Journal.]

SOME PECULIAR FORMS OF IRON. By Prof. T. H. NORTON, University of Cincinnati, Cincinnati, Ohio.

[ABSTRACT.]

STEEL rods which form the interior support of the mantles of the Auer von Welsbach incandescent lamps have been examined after being in use for a year. They are found to have become perfectly brittle, snapping at the lightest pressure. Analysis showed that the amount of carbon had decreased from 0.642% to 0.0978%. The change is interesting as showing the effect on steel of prolonged exposure to the action of the interior of the Bunsen flame.

A sample of iron taken from a fissure in the bottom of a blast-furnace, where it had apparently remained for a long time in a molten condition, showed somewhat exceptional properties. It is of a light white color, with very marked crystalline structure and a strong tendency to cubical cleavage. It is exceedingly tough and very malleable, but it is impossible to secure satisfactory drillings.

Analysis showed the following composition:—

Mn	= 0.0362%
Si	= 0.0262
S	= 0.0106
P	= 0.8285
C	= 0.1035

This sample owes its peculiar properties evidently to the large amount of phosphorus present.

[This paper will be printed in the Journal of the American Chemical Society.]

ON THE EXISTENCE OF ORTHO-SILICIC ACID. By Professor T. H. NORTON, University of Cincinnati, Cincinnati, Ohio.

[ABSTRACT.]

THE probable existence of ortho-silicic acid, H_4SiO_4 as forming the gelatinous precipitate obtained by the action of acids on solutions of the alkaline silicates, or by the decomposition of the halogen compounds of silicon by water, has been dwelt upon by several authors. All proof of the fact has, however, failed on account of the inability to isolate the compound by ordinary methods. The author has succeeded in isolating the compound, and subjecting it to frequent analyses, by taking the precipitate yielded from running a current of silicon tetrafluorid into water, removing the water first by rapid suction on a filter, and then by washing it quickly with ether or benzene. The last traces of the latter are removed by pressing between sheets of bibulous paper. The light white powder thus obtained gives analytical results closely in accord with the formula H_4SiO_4. It gives up its water easily when simply exposed to the air, and offers the same phenomena already observed by chemists in exposing the silicic precipitates to the action of dry air or a vacuum.

[This paper will be printed in the Journal of the American Chemical Society.]

VOLATILITY OF CERTAIN SALTS. By Prof. T. H. NORTON, University of Cincinnati, Cincinnati, Ohio.

[ABSTRACT.]

THE method recommended by Bunsen for testing the comparative volatility of salts by bringing quantitative amounts on platinum wires into the hottest part of the non-luminous flame, and noting the time required for complete volatilization was employed. The following results were obtained with four salts hitherto not subjected to the test, the volatility of sodium chlorid being taken as unity.

	(NaCl = 1)
$Na_2B_4O_7$	16.5
NaF	8.
KF_4	3.
$BaCl_2$	120.

On account of partial decomposition, leaving behind alkaline residues, no satisfactory results were obtained by using $CaCl_2$, $SrCl_2$, or $MgSO_4$. There was a total absence of volatilization on the part of $CaSO_4$ and CaF_2.

[This paper will be printed in the Journal of the American Chemical Society.]

A NEW GAS AND OIL FIELD. By Prof. E. H. S. BAILEY, University of Kansas, Lawrence, Kansas.

[ABSTRACT.]

WITHIN the last twelve months, an extensive gas and oil field has been developed in southeastern Kansas. The author has visited the wells and obtained samples of the oil, which have been subjected to fractional distillation. The specific gravity and flash-point of these oils has been determined. Many facts relative to the occurrence of the oil, and its abundance, and in reference to the quality of the gas, its pressure, and methods of utilizing it, have been obtained.

[The entire paper will appear in the Report of the Kansas State Bd. of Agric., Vol. XIV.]

ACTION OF NITRIC ACID UPON THE CHLORIDS OF ZINC, BISMUTH, AND CADMIUM. By Prof. O. C. JOHNSON, Ann Arbor, Mich.

[ABSTRACT.]

ONE gram of zinc chlorid was added to 25cc. of nitric acid sp. gr. 1.42. After heating on the water-bath until only 20cc. remained, it was found that the chlorid was completely changed to a nitrate, no trace of a chlorid remaining. The chlorids of bismuth and cadmium gave similar results.

H. Wurtz in 1858 found that after evaporating to dryness, adding more acid, and repeating the evaporation six times, much chlorid still remained. Our experiments upon all the other chlorids agree exactly with those obtained by H. Wurtz.

ON THE GRADE OF ETHERNARCOSIS IN RELATION TO THE AMOUNT OF INHALED ETHER VAPOR. By PROF. JOHN G. SPENZER, WESTERN RESERVE UNIVERSITY, Cleveland, Ohio.

[ABSTRACT.]

BUT few investigations have as yet been published on the amount of chloroform and ether in the inspired air, in the act of chloroforming and etherizing persons and animals.

Snow [1] and Dreser [2] through physical means found the percentage of ether vapor (in a mixture of ether and air) necessary to produce anæsthesia to be 3.5%; the author's experiments made in a chemical way check the results of these investigators very well.

The mixtures of air and ether were made in a gasometer, the ether being measured by means of a novel and very accurate appliance.

The administration was carried on by means of an ingenious mask, as well as by direct introduction into the trachea.

[1] "Papers on Narcotism by Inhalation." London Medical Gazette, Vol. 41-42.

[2] "Ueber die Zusammensetzung des bei der Æthernarkose geathmeten Luftgemenges." Beiträge zur Klinisch. Chirurgie Bd. 10, S. 412.

The different stages of anæsthesia were noted, and the mixtures subsequently analyzed gave from their combustions the percentage of ether present, the carbon dioxid produced alone being taken into account.

The taking of a sample of the mixture was readily and exactly done by means of a portable arrangement. Rabbits, cats, and dogs were employed in the experimentation.

[To be published entire in the Journal of the American Chemical Society.]

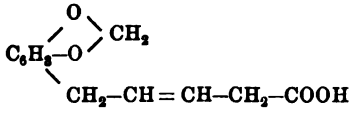
ON THE BEHAVIOR OF ALLYLMALONIC, ALLYLACETIC, AND ETHYLIDENEPROPIONIC ACIDS WHEN BOILED WITH CAUSTIC SODA SOLUTION. BY PROF. JOHN G. SPENZER, WESTERN RESERVE UNIVERSITY, CLEVELAND, OHIO.

[ABSTRACT.]

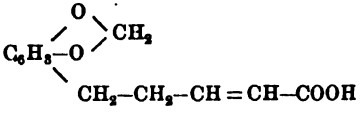
THE first light on the conduct of the unsaturated organic acids when treated with sodium hydroxid was given by the studies of *Fittig* and *Buri*,[1] in 1883.

These chemists, acting on piperic acid by means of sodium amalgam in neutral solution, obtained the then known, and now called α-hydropiperic acid. When, however, they allowed the mixture to become strongly alkaline, it was found that β-hydropiperic acid was also formed. Through subsequent experiments *Buri* showed that it was very easy to obtain β-hydropiperic acid from the α-acid by boiling with caustic soda.

Weinstein[2] and *Regel*,[3] a few years later, while engaged in the study of these two isomeric hydropiperic acids in their behavior to bromin and bromhydric acid, as also in the oxidation with potassium permanganate, came to the interesting conclusion that the α-hydropiperic acid is a $\beta\gamma$-unsaturated, and the β-acid is an $\alpha\beta$-acid, as follows: —



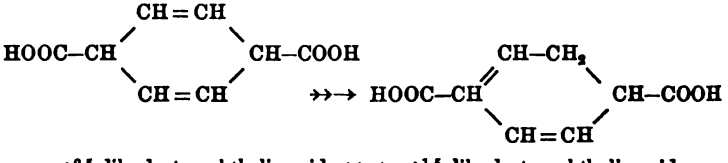
α-hydropiperic acid ($\beta\gamma$)



β-hydropiperic acid ($\alpha\beta$)

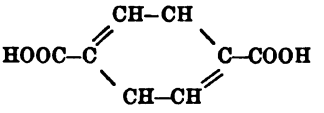
This moving of the double union towards the α-carboxyl was soon observed in other cases, both by the use of caustic soda, and of hot water alone.

Baeyer[4] observed, that $\Delta^{2\cdot5}$ dihydroterephthalic acid by boiling with water went over into $\Delta^{1\cdot5}$ dihydroterephthalic acid, and this in turn was converted into the $\Delta^{1\cdot4}$ dihydroterephthalic acid through the action of caustic soda, as: —



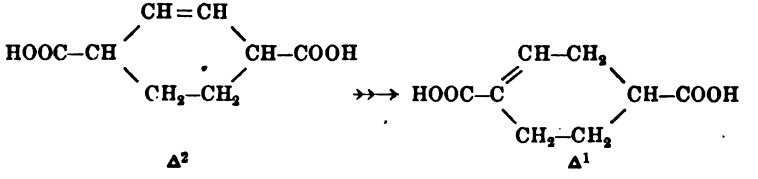
$\Delta^{2\cdot5}$ dihydroterephthalic acid $\rightarrow\rightarrow\rightarrow$ $\Delta^{1\cdot5}$ dihydroterephthalic acid.

[1] Liebig's Annalen, 216, 171.
[2] Ibid. 227, 31.
[3] Berichte d. Deutsch. Chemischen Gesellschaft, 20, 414.
[4] Liebig's Annalen, 251, 257.



$\Delta^{1,4}$ dihydroterephthalic acid.

Baeyer also showed that Δ^2 tetrahydroterephthalic acid is changed to Δ^1 tetrahydroterephthalic acid by sodium hydroxid.



Δ^2 Δ^1

Finally, *Baeyer* and *Rupe*,[1] by the same treatment, converted hydromuconic acid into an isomeric $\alpha\beta$-acid

$$HOOC-CH_2-CH=CH-CH_2-COOH \rightarrow\rightarrow HOOC-CH_2-CH_2-CH=CH-COOH$$

$\beta\gamma$-hydromuconic $\rightarrow\rightarrow$ $\alpha\beta$-hydromuconic

Even previous to this, *Fittig*[2] had come to the conclusion that in the potassa fusion of hydrosorbic acid that the double union must be changed from the $\beta\gamma$- to the $\alpha\beta$-position, since the splitting thereby occasioned occurs at the $\alpha\beta$-position with the formation of butyric and acetic acids; still hydrosorbic acid is undoubtedly a $\beta\gamma$-unsaturated acid, which therefore must split into two molecules of propionic acid.

All these experiments lead to the conclusion that the shoving of the double union towards the α-carboxyl group was general.

Fittig, through his pupils, undertook therefore to prove this, on a list of unsaturated $\beta\gamma$-acids, and it has as yet not been found to fail.

Of the "Aromatic Acids" which have been taken up other than the hydropiperic acid, the following may be mentioned:—

Hoffmann obtained from the phenyl-$\beta\gamma$-pentinic acid, the phenyl-$\alpha\beta$-pentinic acid.

Luib converted phenylisocrotonic acid into benzylacrylic acid.

In the "Fatty Series" the same change takes place, thus:—

Baker procured from hydrosorbic acid, β-propylacrylic.

Feurer produced from $\beta\gamma$-isoheptylic acid, isobutylacrylic.

Weill, from $\beta\gamma$-isoctylic, made $\alpha\beta$-isoamylacrylic acid.

A statement by *Zincke* and *Küster*,[3] that a $\gamma\delta$-unsaturated acid should allow its double union to be moved, toward the α-carboxyl group, and thereby produce $\alpha\beta\gamma$-, and this, through a further shoving, form an $\alpha\beta$-acid, caused the author of this paper to test the truth of this point on two members of the "$\gamma\delta$ series."

According to *Zincke* and *Küster*, allylacetic acid should, through the action of

[1] Liebig's Annalen, 256, 1. [2] Ibid. 255, 13.

[3] Berichte d. Deutschen Chemischen Gesellschaft, 24, 909.

hot sodium hydroxid, be changed to ethylidenepropionic acid, and this in turn to propylideneacetic acid as follows: —

$CH_2=CH-CH_2-CH_2-COOH$, allylacetic acid ($\gamma\delta$)
$CH_3-CH=CH-CH_2-COOH$, ethylidenepropionic acid ($\beta\gamma$)
$CH_3-CH_2-CH=CH-COOH$, propylideneacetic acid ($\alpha\beta$)

Repeated and carefully conducted experiments on allylacetic, as well as allylmalonic acid, however, gave no traces of a $\beta\gamma$- or $\alpha\beta$-acid. This passive conduct of both of these representatives of the "$\gamma\delta$ series" is consequently the more astonishing, since, according to analogy taken from the hitherto observed inclination of terminal methylene radicals, to form methyl groups, — as, for instance, *Faworsky*[1] found in the unsaturated hydrocarbons, — a complete change might be expected here.

On the other hand, *Baeyer*[2] has verified these exceptions to *Faworsky's* rule in the case of the hydrated phthalic acids.

Finally, if this indifference to boiling caustic soda should be asserted in other $\gamma\delta$-acids and become a general characteristic of the "$\gamma\delta$ series," then through this means a sharp and decided distinguishing property has been discovered, between the $\gamma\delta$- and $\beta\gamma$-unsaturated acids, which, moreover, behave alike in the substitution of hydrobromic acid and the decomposition of the product, by means of water and alkalies (Messerschmidt);[3] as also in the substitution of bromin (Urban);[4] and in the treatment with potassium permanganate (Urban).[5]

The $\beta\gamma$-acid, ethylidenepropionic acid, give, with hot caustic soda, propylideneacetic and β-oxyvalerianic acids, which are each very characteristic.

It was the author's good fortune, during his studies on the products of this last reaction, to obtain the first pure propylideneacetic acid, which above 8½°C. is liquid.

It forms very characteristic salts. Both the monobromid and the dibromid are crystalline. They both crystallize in the monosymmetric system, — the monobromid forming beautiful large prisms with 14 faces.

It is very easy to distinguish between the 3 isomers, allylacetic, ethylidenepropionic, and propylideneacetic acid through their salts and bromids.

β-oxyvalerianic acid seems to remain liquid as yet, and also forms characteristic salts.

How is this moving of the double bond of union brought about?

Even from the first, investigators on the shoving of the double bond, through the influence of caustic soda, busied themselves with efforts to explain the mechanism of the reaction.

Based on analogous reactions, *Weinstein*[6] suggested that an oxyacid was formed as a middle step by taking up a molecule of water, which it again gave up with the production of the isomeric $\alpha\beta$-acid, as follows: —

(1) $R-CH=CH-CH_2-COOH+H_2O = R-CH_2-CH(OH)-CH_2-COOH$
($\beta\gamma$-unsaturated) (β-oxyacid)

(2) $R-CH-CH(OH)CH-COOH-H_2O = R-CH_2-CH=CH-COOH$
($\alpha\beta$-unsaturated.)

[1] Journal f. prakt. Chemie, 44, 212.
[2] Liebig's Annalen, 269, 150
[3] Ibid. 208, 93.
[4] Ibid. 268, 60.
[5] Ibid. 268 32.
[6] Liebig's Annalen. 227, 31.

Weinstein was himself unable to isolate this purely hypothetical oxyacid, still it has been found repeatedly since. The theory of *Weinstein* seems to be the most satisfactory one as yet, although *Hoffmann* believes the oxyacid to be secondary to the formation of the $\alpha\beta$-acid, and thinks it is produced from the latter.

The author's, as well as Baker's and Feurer's, experience seems to favor the Weinstein theory.

In a recent publication,[1] *Fittig* and *MacKenzie* have applied the terms $\gamma\delta$-, $\beta\gamma$-, and $\alpha\beta$-pentinic acids to allylacetic, ethylidenepropionic, and propylideneacetic acids respectively.

THE TEST OF FLUORIN FOR THE DETERMINATION OF THE ANTIQUITY OF FOSSIL BONES. By THOMAS WILSON, U. S. National Museum, Washington, D. C.

[ABSTRACT.]

IT is greatly to be desired that some test should be discovered by which the fossiliferous condition of animal bones might be determined.

This test is believed to have been found in Fluorin. It may not be certain nor always equal; but if it furnishes, or promises to furnish, an aid in this direction, it is to be studied, examined, experimented with, and proved. Modern animal bones have but a small percentage of fluorin, say .016 or .017, while it appears to increase in its quantity and proportion until it reaches in those of the earlier geological ages the proportion of 3, or 4 per cent. This increase may be different in different localities, but it seems to be quite regular in a large number of specimens.

THE POLYMERIC MODIFICATIONS OF PROPIONIC ALDEHYDE, PARAPROPIONIC ALDEHYDE AND METAPROPIONIC ALDEHYDE. By Dr. W. R. ORNDORFF, Cornell University, Ithaca, N. Y.

[This paper will be printed in The American Chemical Journal.]

OBSERVATIONS REGARDING CERTAIN EUROPEAN WATER SUPPLIES. By Prof. WILLIAM P. MASON, Rensselaer Polytechnic Institute, Troy, N. Y.

[This paper will be printed in the Engineering News.]

FALLACIES OF POST MORTEM TESTS FOR MORPHIN. By Dr. DAVID L. DAVOLE, Jr., University of Michigan, Ann Arbor.

[This paper will be printed in the Journal of the Americal Chemical Society.]

A CONVENIENT MILK SAMPLING TUBE. By M. A SCOVELL, Director of the Kentucky Agricultural Experiment Station, Lexington, Ky.

[1] Dissertation, Strassburg, 1894.

Report of Committee on Water Analysis.

Your committee appointed to secure uniform methods of stating water analysis report that they sent out a number of circulars, asking for and offering suggestions as to the mode of arranging the results, and endeavored to secure some agreement among chemists on this point.

One object, that of having the results stated in parts per million or milligrams per litre, has practically been attained, nearly all recent analyses being given in that way. They found, however, that it appeared impossible to secure any satisfactory uniformity as regards the nomenclature and arrangement of the chemical constituents found by analysis to be present in the water.

As further progress seems impossible, your committee beg to be discharged.

C. C. Caldwell, Chairman.
William H. Seaman.
W. P. Mason.

TWELFTH ANNUAL REPORT OF THE COMMITTEE ON INDEXING CHEMICAL LITERATURE.

THE Committee on Indexing Chemical Literature presents to the Chemical Section its twelfth annual report. During the current year the following bibliographies have been printed in the channels indicated:

1. Index to the Literature of Didymium, 1842–1893. By A. C. Langmuir. School of Mines Quarterly [Columbia College, New York], Vol. XV. pp. 33–47. November, 1893.

In this index the author follows the plan originally proposed by H. C. Bolton in 1870.

2. The Tannins, a monograph on the history, preparation, properties, methods of estimation and uses of the vegetable astringents. With an index to the literature of the subject. Vol. II, the Tannins of oak-bark, mangrove, canaigre, chestnut. By Henry Trimble. Philadelphia, 1894. pp. 172. 12mo. Ill.

This forms the second volume of the work previously noted in our reports. The carefully compiled bibliography contains about 325 titles.

Reports of progress have been received from several chemists: Prof. Arthur M. Comey announces that the first volume of his Dictionary of Chemical Solubilities, devoted to inorganic compounds, has gone to press and will be published before the close of the year. The second volume is also in active preparation.

Dr. Alfred Tuckerman reports that the United States Section of his Bibliography of Mineral Waters will be ready for the printer in a few months.

Prof. Clement W. Andrews states that he had done much work on a Bibliography of the Polariscopic Determination of Sugar; but, learning that Prof. H. W. Wiley, chief chemist of the U. S. Department of Agriculture, was engaged in a similar undertaking, generously handed over to him all the material he had accumulated. The combined manuscripts have recently been returned to Professor Andrews who will continue the work.

Prof. H. W. Wiley reports great activity on the part of the Division of Chemistry of the U. S. Department of Agriculture in the preparation of bibliographies and special indexes, but he is obliged to admit difficulties in securing the printing of the manuscripts. We quote the following paragraphs from his letter dated June 29, 1894, addressed to the chairman of the committee: "The elegant bibliography of heavy metals occurring in canned goods, by Mrs. K. P. McElroy, has not yet found an avenue for publication." . . . "We also have a very complete bibliography of carbohydrates from the point at which they were left by Tollens in his Handbuch, in 1888, up to the close of 1892. This work was partly done by myself, but chiefly by Mr. H. E. L. Horton, and we were assisted greatly by receiving many hundred titles from Prof. C. W. Andrews of the Massachusetts Institute of Technology. But what we can do with

such a bibliography, comprising as it does three or four thousand titles, I do not know. The Department of Agriculture will not publish it, it is too large for the Journal of the American Chemical Society and so it lies idle." . . . "A very complete bibliography of agricultural chemistry for the year ending 1893 has also been completed by the committee appointed by the Association of Official Agricultural Chemists, of which Dr. William Frear is Chairman. This bibliography I submitted to the Assistant Secretary of Agriculture with the request that it be published as a part of the Proceedings of the Association, but this request was not complied with. The same committee has in preparation a complete bibliography of agricultural chemistry for the year ending June 30, 1894, and this report will be presented to the meeting of the Association of Official Agricultural Chemists in August at Washington. We shall then have unpublished a complete bibliography of all agricultural chemical topics for the two years ending June 30, 1894."

Mr. P. H. Seymour's Bibliography of Aceto-Acetic Ester is in the printer's hands, and will be published by the Smithsonian Institution during the summer.

Prof. F. W. Clarke reports that he is engaged on a new edition of his Recalculation of Atomic Weights.

Prof. H. C. Bolton has begun a Supplement to his Bibliography of Chemistry, and last winter visited the chief libraries of Italy in search of material.

Dr. H. P. Talbot of the Massachusetts Institute of Technology, with the coöperation of Dr. H. C. Bolton, has begun a second edition of the Index to the Literature of Manganese published by the latter in 1875, with the intention of bringing it down to date.

Prof. James Lewis Howe of Louisville, Ky., reports progress on a Bibliography of the Platinum Metals.

Dr. W. H. Magee, of Cornell University, has completed Indexes to the Literature of Cerium and of Lanthanum, and the MSS. have been approved by your committee, and, together with Mr. Langmuir's Index to the Literature of Didymium, have been recommended to the Smithsonian Institution for publication. The three indexes have been accepted by the Smithsonian and will appear in the Miscellaneous Collections.

Prof. Charles E. Munroe reports that Part II of his Index to the Literature of Explosives does not complete his work, as stated in the Eleventh Annual Report; he is engaged on a continuation.

Dr. Claude Augustus Oscar Rosell's thesis presented to the Columbian University, Washington, D. C., in June, entitled "Investigation of the Properties of Ferric Acid," contains an exhaustive bibliography of the Ferrates and Ferric Acid; the channel of publication is not yet determined.

Prof. J. Christian Bay reports progress on a bibliography of alcoholic fermentation and has commenced a bibliography of glycogen.

The annual reports of this committee are properly confined to the productions of Americans, but the chairman begs leave to direct attention to indications of a growing appreciation of the value of special bibliog-

raphies on the part of European chemists, confirming by their recent and proposed activities the work begun in America, at the chairman's suggestion, now more than twelve years ago. Several European countries have long published periodical bulletins of all books issued in their own lands, but they are as a rule too comprehensive in scope for the convenience of the specialist in science. Since the "Biblioteca Historico Naturalis," published at Göttingen, dropped chemistry from its pages (in 1887) the most useful bibliography of current scientific works has been the well known "Naturæ Novitates" (Friedlaender, Berlin) now in its sixteenth year; however, this trade serial is stronger in German than in other languages and falls short of the completeness desirable.

In technology and technical chemistry the admirable "Repertorium der technischen Literatur" (Leipzig), in its continuation, affords invaluable assistance to the industrial chemist. Recently, too, the following periodical has been established; "Biblioteca polytechnica; internationale Bibliographie der gesammten neuen technischen Literatur, herausgegeben von Fritz von Szczepanski." St. Petersburg and Leipzig, 1893. 8vo. 12 numbers per annum. This includes chemistry pure and applied.

The need of an exhaustive authoritative bibliography of current chemical books of the world is still felt.

In a private letter to the chairman of your committee, Dr. Bechhold of Frankfort on Main announces his intention of publishing a full and complete Index to Current Chemical Literature in all languages on a most comprehensive plan; the first number of this serial will be awaited by chemists with great interest.

Heinrich Wien (Vienna) and F. A. Brockhaus (Leipzig) announce the publication of a Universal Index to the World's Technical and Scientific Literature. This ambitious undertaking is intended to embrace both books and periodicals and to represent all the known literature that has appeared in every part of the world; five parts are projected, viz., chemistry, medicine, mining, photography, electricity.

As most of the members of the chemical section are aware a call has been issued for an International Congress of Applied Chemistry to be held under the patronage of the Belgian government at Brussels in August, 1894. At that meeting it is proposed to found a Review of Reviews of Applied Biological Chemistry in several languages, to contain a résumé of chemical work in that branch from all parts of the world. The secretary general of the congress is Monsieur Sachs, 68 Rue d'Allemagne, Brussels.

At the Congress of Chemists held in Chicago, in August, 1893, your chairman had the honor to read an address on an "International Index to Chemical Literature" (J. Am. Chem. Soc., xv, Oct., 1893), in which he proposed a simple scheme for indexing current periodical chemical publications by international coöperation. It is extremely gratifying to record that the necessity of international coöperation has since been suggested by so weighty an authority as the Royal Society (London). That splendid monument of the bibliography of science, "The Catalogue of Scientific Papers,"

published by the Royal Society, has failed to satisfy the requirements of students in science owing to the lack of a subject-index to the prodigious material classified under the names of the authors; but according to a circular issued by the Royal Society in April, "it is hoped that a key to the volumes already published may be eventually issued." The Royal Society further announces its intention of continuing the Catalogue of Scientific Papers after Jan. 1, 1900, on an enlarged and improved plan, with the aid of international coöperation, and asks for suggestions as to the best methods of inaugurating such a scheme.

Although this report deals with chemistry, it may be proper to mention here an important undertaking in another branch of science, as it affords an additional instance of the progress now making towards international coöperation in bibliography. At the Washington meeting of the International Congress of Geologists a committee on the Bibliography of Geology was appointed for the purpose of preparing a list of the geologic bibliographies now in existence. This work is now approaching completion under the direction of M. Emmanuel de Margerie (Paris), the secretary of the International Committee.

American botanists also are showing their appreciation of bibliographical work. A committee of the Torrey Botanical Club publishes in the Bulletin of the club, an "Index to recent Literature relating to American Botany." This Index was begun in January, 1894, and is continued each month; the arrangement is alphabetically by authors.

At the Chicago Congress of Chemists a committee was appointed to bring about the organization of a triennial (or quinquennial) International Meeting of Chemists. Prof. Frank W. Clarke, one of the members of your committee, is chairman of that body. Perhaps the future World's Chemical Congresses may arrange the publication of an exhaustive Index to the Chemical Literature of the World by international coöperation, either in accordance with the scheme proposed by your chairman in his address at Chicago, or in some more efficient way.

Thus, it is evident that immense progress is being made in the compilation of indexes and bibliographies in many branches of science, in both Europe and America; it is to be hoped that American chemists, who have been in some measure pioneers in the matter, will feel stimulated to still greater exertions than before.

The chairman has a limited number of copies of the Tenth Report containing a list of forty-five Indexes to Chemical Literature, which he will be glad to send to applicants. Communications should be addressed to the chairman, at the University Club, New York City.

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AND

ENGINEERING.

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ADDRESS

BY

MANSFIELD MERRIMAN.

VICE PRESIDENT, SECTION D.

THE RESISTANCE OF MATERIALS UNDER IMPACT.

THE science of the resistance of materials, as taught in text-books and used in the daily practice of every engineer, is mainly that of static conditions where external force is resisted by internal stress. The question of resistance to the impact of falling bodies, liable to occur in machinery, on bridges, and to a certain degree also in buildings, is recognized as important, but it is seldom reduced to computation or made the occasion of careful experiment. Even the fundamental principles and laws regarding it seem often not clearly understood. Hence the subject of this address, which is an attempt to set forth the present state of our knowledge concerning impact and to reconcile some of the apparent paradoxes that often arise in the discussion and application of its principles.

In 1807 Thomas Young announced the fundamental ideas of the resistance of materials under impact. "The action which resists pressure," he said, "is called strength, and that which resists impulse may properly be called resilience." He stated that the resilience of a body is proportional to its strength and extension jointly, and that it is measured by the height through which a given weight must fall to cause rupture. The resilience of beams of the same kind he made proportional to their volumes, as also the resilience of shafts whether solid or hollow. He further suggested that a very high velocity of the moving weight may rupture a body by impact before its full resilience can be developed.

Resilience is thus the capacity of a body to resist applied work, or it is the internal work which can be developed by the energy of a moving body. External force is resisted by internal stress and the resulting deformation is a secondary consequence, but impact is resisted by resilience where the deformation is of equal importance with the stress, for internal work is the product of these two factors.

In Young's time the elastic limit of materials was but vaguely recognized and Hooke's law of proportionality of stress of elongation was often applied to all the phenomena preceding rupture. Young's statements are valid in a general way, but we now know that it is necessary to distinguish between the two cases of elastic resistance and non-elastic resistance. Hence there are two divisions of the subject of impact; first, that of elastic resilience where the molecular forces do not surpass the elastic limit of the material; and, second, that of ultimate resilience where the elastic limit is exceeded and rupture finally occurs.

The problems of elastic resilience are largely theoretical and mathematical. Their discussion begins with Young and has been continued by a long line of investigators to the present time; it forms indeed the most prominent part of the theory of elasticity which has been so thoroughly set forth in the history of Todhunter and Pierson. Starting with Hooke's law of proportionality of stress to deformation, and applying to this the mechanical laws of force, velocity and work, the stresses, displacements and resilience of elastic bodies subject to impact have been deduced. The results thus theoretically found have been confirmed by many experiments as must necessarily be the case, since all the laws of the discussion are those of experiment and experience.

The first problems of elastic resilience were those of bars or rods subject to the longitudinal impact of a moving weight. The vibrations of stretched wires had been discussed by Euler, Lagrange and others, but Navier, in 1823, appears to have been the first to investigate the oscillations and maximum stresses in an horizontal bar due to a weight impinging on its end. Poncelet, in 1829, treated the same problem for a vertical bar subject to longitudinal impact by a falling weight. These discussions showed that for the case of horizontal impact the maximum elongation is a mean proportional between twice the height of fall and the extension due to the same weight when applied gradually, while for verti-

cal impact it is the sum of the static extension and the hypothenuse of a right angled triangle whose sides are this static extension and the dynamic extension stated for the horizontal bar. It is a corollary from this that under the sudden application of a load, which is the particular case of impact when the height of fall is zero, the maximum elongation and hence the maximum internal stress is twice as great as that caused by the same load when applied gradually.

While speaking of Poncelet it is well to pause to remark that his work on industrial mechanics, which contains these investigations, deserves especial mention as the book that marks the beginning of technical education; his conceptions and explanations of these problems of external work and internal resilience may indeed still be regarded as models of clear and accurate reasoning.

The solutions of Navier and Poncelet for longitudinal impact on a bar were approximate in the sense that its weight was regarded as small compared to that of the striking body. Later investigations by Saint Venant, Boussinesq, and others, have completely resolved the problem when the relative masses are taken into account and have also disclosed all the attendant circumstances of duration and intensity of the forces at the surface of impact.

Another important problem is that of transverse impact on a beam giving rise to flexural resilience. The first investigation of this was by Hodgkinson, in 1833, in connection with the discussion of experiments, while the full elastic theory for different ratios of weights of the beam and falling body was developed by Cox in 1848, and later most fully extended by the French elasticians in a similar manner to that of longitudinal impact. The law of proportionality of resilience to volume was shown to be true only when the latter is increased an amount proportional to one-half the ratio of the weight of the beam to that of the striking body, and similar modifications are necessary regarding deflections and internal stresses. In all these problems the velocity of transmission of stress, which is the same as the velocity of sound in the given material, forms an important element, as indeed Young had suggested in 1807 at the very beginning of the consideration of impact resistances.

While the conclusions of all these investigations of elastic resilience are true and valuable, it should never be forgotten that they are only true when the conditions are observed under which

they are deduced, namely, that the elastic limit is not exceeded by the maximum internal stress. Now, while the elastic limit for some materials is as high as one-half the ultimate strength, the elongation up to the elastic limit is small compared with the ultimate elongation, and hence the elastic resilience may be very small, less perhaps than one part in a thousand, compared with the total ultimate resilience. The phenomena of elastic resilience form, indeed, such a small portion of those occurring in practice, that it is difficult to observe them with precision, while those of non-elastic resilience are ever present. Many a misconception has arisen and many a paradox has been founded on the assumption that the theory of the smaller part is applicable also to the larger part of the phenomena.

The investigation of ultimate resilience is necessarily experimental, since beyond the elastic limit no theoretical relation between stress and deformation is known. In 1818, Tredgold made experiments on wooden beams subject to the impact of a falling ball, and concluded that Young's law of proportionality of resilience to volume was not justified. Hodgkinson, in 1835, experimented on cast iron beams under lateral impact from a pendulum and found that the deflections were proportional to the velocities of impact, that the same work was required to break the beam whether struck at the middle or at the quarter point, and that the weight of the beam increased its ultimate resilience, all of which is more nearly in accordance with the elastic theory than perhaps might be expected. In 1849 was published the "Report of the Commissioners appointed to inquire into the application of iron to Railway Structures," which contains some of the most comprehensive and valuable experiments ever undertaken. In view of later practice it was perhaps unfortunate that these were mostly made upon cast iron, but the methods of investigation and the conclusions deduced render this report an epoch-making one in the history of the resistance of materials. Here can only be noted those points relating to impact, on which experiments were made by Hodgkinson, Willis and Galton. Transverse impact on beams by oft-repeated blows of a ball swung as a pendulum, and also by pressure applied by a revolving cam, indicated for the first time the laws of fatigue under repeated stresses; transverse impact with a single blow confirmed Young's theorem of resilience and volume, as the same amount of work was required to rupture a rectangular beam whether struck on its narrow or broad side; and the inertia of the beam was shown

to be an important factor in increasing its resilience. Weights suddenly applied without impact gave deflections nearly double the static deflections and the same ratio was observed in the breaking loads. Experiments on the effects of a load moving with different velocities over a beam showed that the deflection could amount to more than double the static deflection, and the elaborate theoretical discussions of this case by Stokes, together with the evidence given by experienced engineers, form the basis of many practical rules since used in bridge design. The immediate result indeed was the revision of the factors of safety by the British Board of Trade and the establishment of a rule that for cast iron the factor for live load should be double that for dead load.

The thirty years following the middle of the century may be designated as the period of development of the modern methods of static tests upon tensile specimens. In the United States this development, begun by Wade, Rodman, and Plympton, later produced the numerous testing machines of Fairbanks, Olsen and Riehle, and at last has culminated in the precise apparatus of Emery and in the powerful machines at Athens and Phoenixville. These static tensile tests seem to have diverted attention from the question of impact and to have caused the neglect of the theory of resilience, for the objects of the method have been mainly to determine the elastic limit, maximum strength and ultimate elongation, considerations of work having been largely overlooked. Yet the diagram formed by laying off the unit-stresses as ordinates and the corresponding elongations as abscissas shows by its area the internal work which resists rupture and thus is approximately a measure of the ultimate resilience per cubic unit of the material. The phenomena in a slow test, however, are not in all respects the same as in a rapid one, the elastic limit and maximum strength being generally greater in the latter while the elongation is less. How the diagram would look under the very rapid development of stress is yet to be determined, and not until this is done by an autographic device can a full knowledge of the total field of resilience be obtained. High values of the ultimate elongation and contraction of area have been regarded as of great importance in judging of the quality of iron and steel, and this has given rise to what may be called an unconscious manipulation of the machine, the power being applied at such a rate as to secure these results

consistent with other conditions. It is safe to say that stresses are not applied and that rupture does not occur in this manner in practice, and hence it is that static tests fail to give full satisfaction.

It would be easy to take a great deal of space in criticism of the imperfections of the static method of testing, to show the uncertainty of percentages of elongation, to dwell on the discrepant results found from specimens of different shape, and to state the various views regarding contraction of area and the appearance of the fracture. But this is not the place. It may be said again, however, that the work per cubic unit developed before rupture is an important element by the study of which much can be learned, for the total resilience depends not merely on maximum strength and ultimate elongation but upon the rate of variation of these throughout the test. Each material, or specimen, by virtue of its physical and chemical properties and its method of manufacture, has the capacity for resisting a certain amount of applied work of which the quantities measured in the static test are not complete factors. The full resilience can indeed only be found from an autographic diagram like that used in Thurston's torsion machine, which has done good service in this direction.

During all this development of static testing one impact test has survived and everywhere held its own. This is the cold bend test for wrought iron and steel. In the rolling mill it is used to judge of the purity and quality of the muck bar, in the steel mill it serves to classify and grade the material almost as well as chemical analysis can do, and in the purchase of shape iron it affords a quick and reliable method of estimating toughness, ductility, strength, and resilience. It is true that numerical values of these qualities are not obtained, but the indications are so valuable, that if all tests except one were to be abandoned the simple cold bend test would probably be the one which the majority of engineers would desire to retain.

Returning now to impact experiments proper, the experiments of Kirkaldy, in 1862, deserve notice. He subjected wrought iron specimens to sudden tensile stress by loads which were applied without velocity, and found that they broke with 82 per cent less load than under static conditions. This has since been quoted as a contradiction of the law that the stress produced by a gradual

load is one-half that caused by the same load when suddenly applied, but really no contradiction exists, since the law is only true whan the elastic limit is not exceeded. For ultimate resilience the ratio of gradual to sudden load producing the same stress is always greater than one-half and approaches nearer to unity the more ductile the material. Kirkaldy also introduced the ultimate contraction of area as an element of equal importance with the ultimate elongation, and undoubtedly this is the case since it is subject to less variation with the length of the specimen. However, little satisfactory evidence exists that contraction of area is a measure of resistance to impact, as some have supposed.

The impact hammer or ram delivering repeated blows, as used by Sandberg and Styffe in 1868 on railroad rails and by the United States Board for Testing Metal in 1878 in experiments on chain iron, is perhaps the most common method of conducting tests for resilience. The weight of the ram multiplied by the height of fall measures the work done in one blow, and the number of foot-pounds required to produce rupture furnishes an index of the ultimate resilience of the bar or specimen. Although valuable for comparative purposes, like the cold bend test, this method fails to give proper numerical results, since the effect of a second blow is not really added to that of the first on account of the dissipation of internal work into heat which follows the release of the stress when this is greater than the elastic limit. That the work of several blows affords little indication of ultimate resilience was well shown by Uchatius, in 1874, who experimented on rods of small size under the impact of a small ram, and found that rupture could be caused by 1 blow of 28 inches fall giving 6 foot-pounds, by 4 blows of 21 inches fall giving 18 foot-pounds, by 37 blows of 10½ inches fall giving 83 foot-pounds, or finally by 2050 blows of 3½ inches fall giving 1536 foot-pounds of work. Indeed the fact that one strong blow is more efficient than many weak ones is well known to every artisan. The comparative weights of the ram and bar are also of importance in such tests, as will be later noticed.

The rise of the elastic limit after the release of a stress which surpasses it, first shown by Thurston in 1873, and the consequent stiffening of the material under several such applications of stress, are also observed in cases of repeated impact. Thus Martens, in 1879, tested a railroad rail by a ram falling alternately on the

head and base; the second blow produced only 95 per cent. of the deflection caused by the first, and after four or five blows only 90 per cent. was obtained. Here, of course, a large part of the work of each blow was dissipated in heat due to the change of molecular structure so that the total work expended gives no valid numerical measure of the true ultimate resilience of the material. Our knowledge as to what occurs under such repeated impacts is of the most uncertain kind. Most of the stresses are no doubt injurious as the final result proves, but a few may perhaps be beneficial in improving the quality of the material like the process of cold-hammering and cold-rolling in manufacture. Baushinger's discovery in 1885, that the raising of the tensile elastic limit is accompanied by a lowering of the compressive elastic limit, is a most important one which is likely in connection with future investigations to lead to a clearer knowledge of the laws of stress in materials under repeated impact.

The investigations of Wöhler between 1860 and 1870, and the later ones of Spangenberg, on the resistance of materials under repeated stresses applied with little impact, have been of the greatest value in influencing the rational design of bridges and other structures subject to variations of load. They established the facts that repeated stresses below the elastic limit do not injure the material, that repeated stresses beyond this limit cause injury in proportion to the range between the maximum and minimum limits, and that the greater the range the less the number of repetitions required to produce rupture. The prompt adoption of rules for designing based on these conclusions, in place of the arbitrary methods of adding 20 or 30 per cent to the static stresses, indicated that the engineering profession appreciated the importance of providing for the resistance to impact in a rational way. Yet probably greater impacts occur on bridges than these repeated stresses, for failures are not infrequent and the life of a bridge under heavy traffic scarcely exceeds a dozen years. The further study of the effect of repeated impact is thus imperative, for what we now know is but little compared to what is to be learned.

Maitland, in 1887, showed by many experiments on tensile specimens subject to many blows of a falling ram that the ultimate elongation was greater than in static tests, it being in some cases nearly doubled. This perhaps might be expected from what has been said regarding the beneficial influence of some of the stresses.

He also exploded powder and gun cotton between two cylinder heads joined together by rods and found their ultimate elongation to be more than double the corresponding ones under static stress. This, on the other hand, might not have been expected from the general conclusions regarding the effect of time on stress and elongation, and it seems not to be the case for the impact of a single blow in later experiments. Thus, it appears, in problems of ultimate resilience, where no theory has yet been developed, that general principles derived from static tests should be applied with caution.

The tests made by Estrada, in 1893, have recently led to much interesting discussion on the subject of impact. Specimens of wrought iron and steel were tested by the usual tension machine and also under the blow of a ram weighing one hundred pounds falling through vertical heights ranging from five to twenty-five feet. Over forty specimens were broken under repeated blows, they being so arranged that they were brought into tension by the pressure caused by the impact. The number of blows ranged from two to fourteen, the height of fall varying in different cases. These valuable experiments show clearly that the ultimate elongation under repeated impact is greater than for static stresses, the average of all being about one-third greater while the contraction of area shows only a small increase; but no conclusions regarding the elastic limit or the maximum strength under impact can be derived from them. The impact was not directly applied to the specimen but to a number of plates and bolts through which it was transmitted and thus much of the work was spent in acting against their inertia and resilience. This, however, in no way invalidates the important deductions regarding the influence of repeated impact on ultimate elongation and contraction of area, and the conclusion of Kirkaldy regarding the value of the latter as an index of toughness and ductility is thoroughly confirmed. The elongation before rupture appears to vary approximately as the amount of work expended by the ram, but the work required to produce rupture does not give a satisfactory comparison of the ultimate resilience of different specimens except in those cases where the height of fall was the same.

The experimental work thus briefly reviewed has been done by special improvised apparatus and with little or no uniformity of method, but the time may come when the machines for impact tests

will be put on the market and be in common use. At present almost the only one that can be mentioned is that devised by W. J. Keep, about 1889, for testing the resilience of cast iron. The blows are delivered by a hammer weighing twenty-five pounds, falling like a pendulum through heights less than six inches, and produce horizontal flexure at the middle of a small bar one foot in length. Beginning with a fall of one-eighth of an inch, successive blows are applied, each with a fall one-eighth of an inch greater than the preceding, until rupture occurs. The deflections and sets of the bars are graphically recorded by the machine itself, and thus excellent comparisons of the ultimate resilience of different grades of metal may be obtained.

Impact tests are most important in the case of railroad rails, car wheels, tires and axles, and other forms liable to shock. Such rail tests have been carried on for many years in Europe, and since 1890 in the United States by P. H. Dudley. Already at least three prominent railroads require drop tests of steel rails to be made at the mill. One rail butt 4½ feet long is to be taken from each heat, placed on solid supports with either head or base upwards and a weight of 2000 pounds is dropped upon it, the height of fall being sixteen feet for rails lighter than seventy pounds per yard and twenty feet for heavier ones, while the distance between the supports is three feet for the former and four feet for the latter. Under this test ninety per cent. of the rails must not break, and the elongation of the base or head under the greatest tension must be more than five per cent. This requirement of testing by a single blow is in every respect more satisfactory than by several repeated ones as the deflection and deformation are produced by a known quantity of work and the complex phenomena of stiffening and the loss of work in heat are largely avoided.

It is to be hoped that the many important experimental results obtained by Dudley in conducting these tests may soon be published. By his kind permission I can here state, however, that they indicate that the deflection is proportional to the height of fall of the ram instead of to its square root as in elastic resilience, that both the deflection and the extension on the tensile side are slightly less than in the usual static tests of rupture by flexure, and that the elastic law of proportionality of resilience to volume seems not to apply. His experiments, now in progress at Scranton, promise to give most valuable information regarding the intensity

and variation of the pressure between the ram and the rail at the moment of impact; while, by measurements of the extensions and compressions over the whole length of the base and head, data are obtained which will render possible a satisfactory computation of the actual internal resilience developed by the applied work.

Aside from the physical qualities of the metal, impact tests on rails and wheels promise to give important conclusions regarding the influence of temperature, of chemical composition, and of methods of manufacture, and thus to lead to a better, more uniform and cheaper product. The discovery by Goss, in 1892, that the driving wheels of a locomotive lift up from the rail during a part of each revolution when moving at high speed, shows that impacts are of more common occurrence than generally supposed, and to resist these satisfactorily an increased resilience in wheels, rails and bridges is required.

At the closing session of the Engineering Congress held last year in Chicago a resolution was offered by Debray that uniform methods of testing are desirable for purposes of comparison, and it was adopted unanimously. For common static tests of tension and compression the time has certainly arrived when rules to secure uniformity should be framed and followed. The conferences held at Munich in 1884 and at Dresden in 1886 made a good beginning, and the later work done in 1891 by the Committee of the American Society of Mechanical Engineers will undoubtedly bear good fruit. With respect to impact, however, our knowledge is not yet sufficient to frame uniform rules. The recommendation that the weight of the anvil, or supporting blocks which hold the specimen, should be at least ten times that of the ram, is an excellent one, but others fully as important will doubtless be developed by further rational investigation and experiment.

The influence of the inertia of the resisting body in modifying the effect of the impact should not be forgotten. If the ram be light local damage in the body struck will be the result rather than the development of its resilience. Cotterill has suggested for the case of transverse impact that if the total work of the ram be taken as proportional to its weight plus one-half the weight of the beam, then the work spent in developing resilience may be taken as proportional to the weight of the ram and that spent in local damage to one-half the weight of the beam. This is a good rule to keep in mind, for longitudinal impact producing pure tension,

one-third being the fraction to be used instead of one-half. The fall of the ram should not be too great, for a high velocity of impact is also apt to cause the work to be spent locally since time is required for the transmission of internal stress. The cutting of hard steel plates by the impact of particles of sand at high velocities is an example familiar to engineers, and that drops of water will wear away stone is known to all. Hence a low fall combined with a heavy ram seems best adapted for conducting impact tests where the most satisfactory numerical results are derived.

It may further be suggested that the blow should be delivered directly to the beam or specimen without the intervention of intermediate blocks or parts which may absorb work. At the same time the surface of contact should be sufficiently large so that the compression of the ram may not, if possible, exceed the elastic limit, and thus loss of work in heat be avoided. In elastic resilience the applied work is not transformed into heat, in resilience accompanied by permanent deformation it is, and hence the tests should be so conducted that the specimen and not the ram may be heated. Lastly it may be noted that the rebound of the ram should be subtracted from the total fall to give an exact measure of the work actually performed by it upon the body which is tested.

The violent impacts due to the explosion of dynamite, or to projectiles striking against armor plates, constitute a branch of the subject which can receive but a moment's attention here. In such cases the velocity of impact is so great that the time for the development of resilience by the distribution of internal stress is very short. The velocity of the transmission of stress in steel is about 17000 feet per second, and a velocity of 2000 feet per second is probably very near the limit where a projectile may be expected to cause local damage of some kind. The stresses in this case are those of direct compression or rather pulverization, and perhaps even combustion may occur under the intense heat developed. Formulas for penetration based on shearing stresses have little validity under such extreme conditions, and the material on the surface of modern plates is one whose physical properties are quite unknown except in respect to hardness. Indeed the subject of these violent impacts is one for which no theory will long be possible, although Boussinesq made a beginning in 1882 for the case where the elastic laws are observed. However the indications are that, in the conflict for supremacy between projectile and plate, the former has the better chance for ultimate success.

Having now passed over in rapid review the state of our knowledge of the resistance of materials under impact, a brief consideration should be given to the contradictions or paradoxes that constantly arise in discussions of the subject. Of these the most common is that the theory of elastic resilience is incorrect because it is not verified by the phenomena of ultimate resilience. It has already been pointed out that the principles of the two cases are necessarily different. It is a principle of elastic resilience that a force suddenly applied to a rod or beam produces double the elongation and double the stress caused by the same force when gradually applied, but this is not true when the elastic limit is exceeded and it should not be expected to be true when materials are tested to destruction. Hodgkinson found it closely verified for cast iron, but this is because the ratio between stress and elongation of that material is not subject to wide variation while an elastic limit scarcely exists. Kirkaldy found it not verified for wrought iron, and this is because of its great elongation beyond the elastic limit. So with the deflection of beams under ultimate resilience, cast iron agrees fairly with the elastic law while wrought iron does not, and the reason is the same as before. So with the elastic law of the proportionality of resilience to the volume of the bar, cast iron is found to fairly agree under conditions of rupture while wrought iron and steel probably do not, and in neither case are the elastic laws affected. The old paradox in the theory of beams is of a similar nature; the modulus of rupture derived from the static formula does not agree with the tensile or compressive strength of the material, but this in no wise reflects on the truth of the formula whose theory supposes that the elastic limit is not exceeded.

The numerous efforts to compute the pressure caused by the impact of a ram form a series of paradoxes which originate in defective mechanical conceptions. The frequent assumption that the pressure is equal to the momentum is one of these which has, of course, no reasonable basis, except in the particular case when the ram is brought to rest by a uniform resisting force in one second of time. The assumption that the pressure varies directly with the fall, or with the work done by the fall of the ram, has no reasonable basis at all. The correct principle here is, as well elucidated by Skinner in 1877, that the mean value of the pressure multiplied by the distance through which it acts is equal to the total work done

in the fall, but this gives no idea of the variation of the pressure or of its maximum intensity except for a few problems in elastic resilience.

In recent discussions of Estrada's tests the paradox of equating foot-pounds of work to pounds of stress has arisen, with the result that it has been claimed that the elastic limit drops almost to zero in cases of impact. It is scarcely necessary to note here that the principles of mechanics lead to no such conclusion. As already stated, elastic resilience forms so small a part of total resilience that it often passes unobserved, but resilience is not stress and there is no way in which they can be correlated except by combining the latter with the deformation that it produces. Keep's tables for impact are nothing more than the statement that the pressure produced by a blow is 5.42 pounds for each inch-pound of work, but it should be said that he fully regards this as arbitrary and valuable for comparative purposes only.

These unnecessary paradoxes and misunderstandings can be dispelled only by a clear conception and correct application of the fundamental laws of mechanics. The definitions of force and stress, work and energy, and all the words employed, must be clearly understood, and the law of conservation of energy be made the basis of every step of the reasoning. Too great attention cannot be given in our technical schools to the elucidation of these fundamental conceptions in view of the lack of precision which is so frequently apparent. Even the discussions of Herbert Spencer in the first volume of his phllosophy appear poorly adapted to inculcate sound principles; for there are no laws of persistence of force and of continuity of motion as his words imply, but the phenomena of both force and motion are merely consequences of the great law of energy, and in any particular case either force or motion may vanish as the energy becomes either kinetic or potential. Language is ofttimes an imperfect instrument for communicating thought and algebra usually beclouds the reasoning whose tool it is; hence, it seems to me that these fundamental conceptions may be better fixed in the minds of students by practical experiments and numerical computations than by the mere study of books and the solution of algebraic exercises. The laws of mechanics are the laws of experience, and the best knowledge of nature is the solid ground of direct interrogation and investigation.

In conclusion it may be noted that the pages of engineering liter-

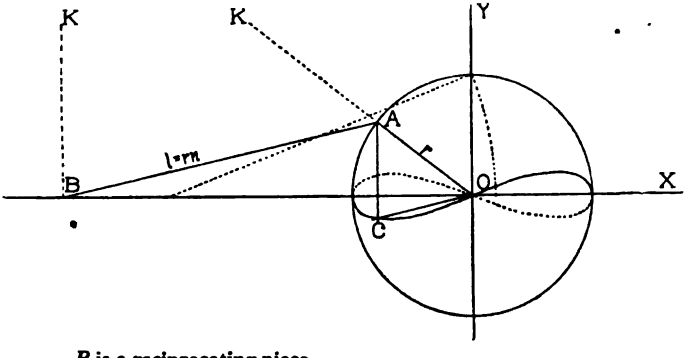
ature contain much testimony as to the importance and value of impact tests. As a single example, Baker, the engineer of the Forth Bridge, said in 1884 that, for judging the ductility of metal, the method of direct tension would apply in one case in a hundred, but in the other ninety-nine the simple cold bending of a bar was generally used and was just as sound a test. The idea that the internal resisting work of a material is the best measure of all its physical qualities has been advocated in Germany by Hartig, and the law of proportional resistances announced by Kick, in 1879, indicates a wide field of valuable applications for the future. The theoretical work done in France, the drop tests for rails through all Europe, the experiments of Dudley and others in the United States, furnish additional evidence of the growing appreciation of the value of the study of impact. Indeed it is not too much to hope that, in a few years, methods may be devised by which full numerical information regarding all the physical qualities of materials can be obtained from simple tests of their elastic and ultimate resilience.

PAPERS READ.

THE CRANK CURVE. By Prof. J. H. KINEALY, Washington University, St. Louis, Mo.

[ABSTRACT.]

THIS curve is the locus of a point whose distance from the path of a rotating point, multiplied by the angular velocity of the rotating point will give the velocity of a reciprocating point connected to the rotating one. The distance from the rotating point is always measured along a line at right angles to the direction of motion of the reciprocating point. Points on the curve may be found by dropping from the rotating point a line perpendicular to the path of the reciprocating point, and determining its intersection with a line drawn through the centre of rotation, parallel to the line connecting the reciprocating and the rotating points.



B is a reciprocating piece.
A is a rotating piece connected to B by rod $A\ B$.
Angular velocity of $A = a$.
$B\ A = l = r\ n$, $A\ O = r$.
Draw $A\ C \perp B\ O$, and $O\ C \parallel$ to $B\ A$ intersecting at C.
Call $A\ C$, h.
Velocity of $A = a\ r$.
" " $B = h\ r$.
Locus of C is the curve CO 2.
Angle $A\ O\ C = \theta$
" $A\ B\ C = \phi$

Equations of this curve are:

$$x = r \cos\theta = r\sqrt{1 - n^2 \sin^2\phi}$$

$$y = \frac{-r \sin\theta \cos\theta}{\sqrt{n^2 - \sin^2\theta}} = \frac{-r \sin\phi \sqrt{1 - n^2 \sin^2\phi}}{\cos\phi}$$

$$\phi_{max} = \tan^{-1} \frac{1}{\sqrt{n^2 - 1}}$$

Curve passes through origin at an angle ϕ_1

$$\phi_1 = \phi_{max} = \tan^{-1} \frac{1}{\sqrt{n^2 - 1}}$$

$$Y_{max} = n r - r\sqrt{n^2 - 1} = l - \sqrt{l^2 - r^2}$$

Polar equation of curve is

$$\rho = \frac{r\sqrt{1 - n^2 \sin^2\phi}}{\cos\phi}$$

Polar equation of lemniscate is

$$\rho_1 = r\sqrt{1 - 2\sin^2\phi}$$

If $n^2 = 2$ the curve becomes almost the lemniscate, and

$$\rho = \frac{r\sqrt{1 - 2\sin^2\phi}}{\cos\phi} = \frac{\rho_1}{\cos\phi}$$

This shows that the lemniscate lies between the given curve and the diameter.

PRELIMINARY EXPERIMENTS ON A NEW AIR PYROMETER FOR MEASURING TEMPERATURES AS HIGH AS THE MELTING POINT OF STEEL. By Prof. D. S. JACOBUS, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

THIS paper describes preliminary experiments made in order to show that three of the pyrometers will give concordant results at very high temperature. The pyrometers were placed in a special furnace, and were gradually brought up to the maximum temperature, and were held at this maximum temperature for several hours. This has been done a number of times, and the readings of the pyrometers were found to agree with each other, thus showing that concordant readings are given at extremely high temperatures, and that the pyrometers are unaffected by a heat as high as the melting point of steel.

ON THE PRECAUTIONS NECESSARY IN THE USE OF MERCURIAL THERMOMETERS IN DETERMINING THE AMOUNT OF SUPERHEAT IN STEAM. By Prof. D. S. JACOBUS, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

THE paper shows how errors are often made in determining the amount of superheating in steam in Boiler and Engine tests and in work of a similar

nature, and gives results of experiments on the amount of such errors. The proper method of determining the superheating is described.

IMPROVEMENTS IN METHODS OF TESTING AUTOMATIC FIRE SPRINKLER HEADS. By Prof. D. S. JACOBUS, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

THE complete method adopted in performing the tests is described in detail. The tests now made are much more complete than the first tests for the reason that, as time passed on, and the action of the sprinkler could be noted after several years of actual service, various defects were developed. The present tests are made to cover, as nearly as possible, all features where defects have been noticed, and for this reason the requirements of a successful head are much more severe than in the first tests. The various causes of failure and the requirements of a successful head are fully described.

[This paper will be printed in The Stevens Indicator.]

ON THE RATIO OF EXPANSION OF STEAM IN MULTIPLE EXPANSION MARINE ENGINES FOR MAXIMUM ECONOMY IN FAST RIVER STEAMERS. By Prof. J. E. DENTON, Stevens Institute, Hoboken, N. J.

[ABSTRACT.]

THIS paper shows by numerical examples that in fast river steamboats the use of the ratio of expansion affording the least consumption of steam per horse power requires a greater consumption of fuel for a given amount of transportation than the use of engines using lower ratios of expansion, and consuming correspondingly greater amounts of fuel per horse power.

EXPERIMENTS ON THE TRANSVERSE STRENGTH OF LONG LEAF YELLOW PINE FOR SEVERAL PURPOSES. By SAMUEL MARSDEN, No. 1015 North Leffenwell Ave., Saint Louis, Mo.

[ABSTRACT.]

THIS paper gives the results of a large number of experiments made upon specimens taken from different parts of trees and in different states of dryness.

THE AIR LIFT PUMP. By Prof. ELMO G. HARRIS, Rolla, Mo.

[ABSTRACT.]

A BUBBLE of volume O liberated beneath the water surface in an open vertical tube of cross section A, causes the water within the pipe to ascend to

a height equal $\frac{O}{A}$ above the free surface outside. The bubble tends to occupy one-half the cross section of the pipe, the opposing forces being capillary attraction and surface tension.

The work done in forcing a volume, O, of air to a depth, D, beneath the surface of water moving with a velocity, V, is $211.6\ O \log_e \left(\frac{D - \frac{v2}{2g} + 34}{34} \right)$

A rational formula is produced giving relation between quantity of air used, quantity and height of water discharge, depth of emersion, and area of pipe.

The size of bubble for greatest efficiency is the minimum that will occupy one half the area of pipe.

The pump is best suited for a sand or mud pump, and for elevating sewerage.

The proper construction is without obstructions or contractions in the main pipe.

Two patents cover the Air Lift pump, — one specifies the smallest possible bubble, the other the largest.

The "slip" of the bubble, or the velocity relative to the water above or below, can be definitely established by a simple experiment, which is explained.

SOME REMINISCENCES OF THE EARLY HISTORY OF IRON BRIDGE BUILDING IN THE UNITED STATES. By Prof. GEO. W. PLYMPTON, Brooklyn, N. Y.

[ABSTRACT.]

RESULTS of tests of wrought iron for bridges in 1856 : — These resulted in a rejection of welded bars or rods with screw ends in subsequent structures. The writer was associated with John W. Murphy during the time of these tests. The first structure which was pin-connected throughout was built by Murphy in 1858–9, at Phillipsburg.

Two events occurring during the period of early development of American bridges were stated, one the construction and failure of a Remington bridge in Central New York about 1852, the other the quick construction of a military bridge by Murphy in 1862 in Virginia.

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BY

PROF. SAMUEL CALVIN,

VICE-PRESIDENT, SECTION E.

THE NIOBRARA CHALK.

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IT was my original purpose to take for the subject of this discourse some geological problems in northeastern Iowa, but certain circumstances made it seem more desirable to transfer attention to the northwestern part of the state and discuss the more striking features of the Niobrara chalk.

The Niobrara stage of the Upper Cretaceous is well represented along the Missouri from the mouth of the Niobrara river to the mouth of the Big Sioux. East of the Sioux, beds of the same stage are found at various points in Iowa as far eastward as Auburn in Sac county,[1] while fossils distributed through the drift indicate the former existence of cretaceous strata at points many miles farther east than any localities where they are now known to occur in place.[2]

AREAL DISTRIBUTION.

The general distribution of the Niobrara deposits, it need not be said in this presence, covers an area reaching from western Iowa to the Rocky mountains, while north and south it stretches from Texas to Manitoba and probably northward to the Arctic ocean. It is not my intention to extend the discussion of the formation so as to cover more than a very small fraction of this magnificent area. I purpose rather to limit myself to some of the characteristics of the Niobrara chalk exhibited in the somewhat restricted region lying between the mouth of the river from which the formation takes its name and the most eastern exposure of the beds at present known, near Auburn, Iowa. Within these rather narrow limits all the typical phases of the Niobrara formation are perfectly exemplified, and ample facilities are afforded for the satisfactory study of its composition. Furthermore, it will be remembered that the shore line of the Niobrara sea passed through Iowa, and during the culmination of the conditions that gave us the peculiar deposits of this portion of geological time the sea margin was probably not very far east of Auburn. Indeed it may be shown that the shore line was subject to many movements of advance and retreat, and that during the early part of the Niobrara age the sum of the movements was eastward and the ocean gradually encroached upon the land; while later the reverse was true and the waters retreated towards the west. For these reasons the region to which the discussion is limited affords facilities for determining the effects of varying depths of water and varying degrees of proximity to the shore upon the composition and origin of its sedimentary deposits. In the eastern part of the region we may look for marginal beds of Niobrara age, and farther west we should find contemporaneous beds that accumulated off shore in the clear open sea.

[1] C. R. Keyes, Proceedings Iowa Acad. Sci., Vol. I, part IV, p. 25, 1894.
[2] C. A. White, Proceedings A. A. A. S., Vol. XXI, p. 187, 1872.

PHYSICAL CHARACTERISTICS.

The Niobrara sediments are unique among the geological formations of the Northwest. Where typically developed they are wholly calcareous, or nearly so, and yet they are altogether unlike the limestones that are so common and so characteristic a feature of the geology of the upper part of the Mississippi valley. They lie indeed in massive strata, varying from six inches to more than two feet in thickness, as do some of the limestones, but the material is chalky in appearance and correspondingly soft in texture. The color of freshly exposed surfaces varies from white through shades of gray and yellow. In some instances the weathered surfaces become reddish owing to the final oxidation of the small amount of iron which the beds contain. The material composing what anyone studying the region under consideration would call the typical deposits, may be excavated with pick and spade; it may be carved with the pocket knife; the massive blocks into which the layers are readily quarried may be shaped with the saw with greater ease even than if they were blocks of wood; the material is so soft, indeed, that it cannot be handled without soiling the fingers; it may be used for writing on the blackboard; the mechanic might use it on his chalk lines; in a word, these typical beds to which our attention will be chiefly directed are nothing more nor less than chalk.

It is not to be understood, however, that all the Niobrara deposits of our somewhat circumscribed region are chalky. Some would have to be described as soft calcareous shales, while others are made up of thin-bedded, fissile limestone, sometimes more or less earthy and impure, but composed chiefly of valves of *Inoceramus problematicus* cemented together. It is only the beds that represent what we may call the perfect and ideal product of the conditions that prevailed during Niobrara time that are massive, soft and chalky.

STRATIGRAPHICAL AND BATHYMETRICAL RELATIONS.

Allow me to traverse familiar ground long enough to say that the Niobrara chalk is a part of the Missouri Cretaceous series that was long ago made classic by the labors of Meek and Hayden. The work of Hill and of others in Texas enables us now to refer the beds in question to the Upper Cretaceous, as distinguished from

the Comanche or Lower Cretaceous series of the Southwest. In the region we are considering the Cretaceous begins with the Dakota sandstone, a formation indicative of shallow seas and moderately high contiguous shores. During the deposition of the Dakota beds the water over what we now call Sioux City was shallow and vexed sometimes with conflicting currents, as is shown by the cross bedded sands with oblique planes inclined in many different directions. That the land was high enough to enable the drainage waters to carry coarse mechanical sediments, that it was covered with semi-tropical forests of deciduous trees, and that its surface was watered with a most generous rainfall, are clearly recorded in the material composing the deposits, in the taxonomic relations of the leaves and other organs that make up the profusion of fossil plants which some of the beds contain, and in the brackish-water types composing the rather meager molluscan fauna of the earlier layers. Moreover the region was part of a great area of subsidence. If we limit attention to some given point, for example the bluffs above the mouth of the Sioux river, we shall find certain facts clearly recorded. During the entire time represented by the Upper Cretaceous there may have been many alternations of elevation and subsidence, but at the first the waters were gradually deepened and the shore line became more and more remote. As these processes went forward the coarser sediments, together with the leaves and twigs of the magnificent forest flora clothing the land, all came to rest in the beds laid down near the constantly receding shore, and only the finer clays were carried seaward as far as the point we have selected for consideration. With progressive subsidence the land stood lower, the drainage streams became more sluggish, erosion was less energetic, and it is probable that at this stage even in the marginal sediments the materials were fine clay with little admixture of siliceous sand. At all events, at a short distance from the shore, we have the transition from Dakota sands, with some alternating beds of shales, to the purer Fort Benton clays, which represent the second phase of sedimentation in our selected area during Cretaceous times. The Benton shales are not very thick in this region, probably not more than 40 feet altogether. While they were accumulating the process of subsidence went on, as before, at a rate more rapid than the upward growth of the sedimentary deposits. The lands, that during the Dakota stage had stood high above the sea, were by progressive subsidence reduced

in altitude until finally base level was reached, and the sluggish drainage streams discharging into this part of the Cretaceous basin failed to carry even the finer clay and at last mechanical sediments gave place to those of organo-chemical origin. When these conditions were reached, the region witnessed the beginning of the third phase of sedimentation in the Cretaceous seas, and the Niobrara stage, with its peculiar beds of chalk, was inaugurated. Reviewing for a moment the conditions prevailing in that portion of the region that now lies west of the Sioux river, we may note that the water was clear, moderately deep, and unpolluted by mechanically derived earthy detritus; that the shore line, a portion of the time at least, was a hundred miles to the eastward; that the body of land contiguous to the shore was low and flat, and drained by streams with currents too feeble to bear any contributions from the land to the sea. It was in such a sea and under such conditions that the Niobrara chalk was deposited.

Before the Niobrara age came to a close, the upward movement of the region began. Step by step the sea receded from its line of farthest advance, somewhere east of the middle of Iowa. Progressive elevation of the land quickened into life the practically dead streams of the Niobrara age, and mechanical sediments appeared once more in the Cretaceous sea and settled down upon the surface of the chalk to become the lower beds of the Fort Pierre shales. The Fort Pierre shales are found as far east as Yankton, South Dakota, and recently Keyes claims that they have been identified in northwestern Iowa.[1] In the latitude of Sioux City they may have originally extended beyond the Sioux river. Our region during Cretaceous times witnessed, therefore, a fourth phase of sedimentation. With the incursion of mud that inaugurated the work of building the strata of the Pierre group, the conditions that made the Niobrara chalk possible were brought to an end. The swarming life that furnished the organic skeletons of which the chalk is constructed was unable to maintain existence under the changed environment.

It will be noted that in the Sioux river region the conditions that gave us successively the Dakota, Benton, Niobrara and Pierre deposits passed one into the other by practically imperceptible gradations. While in the Black Hills the transition from the Dakota sands to the Benton shales is very abrupt, along the Sioux river

[1] Proceedings Iowa Acad. Sci., Vol. I, part IV, p. 25, 1894.

the transition is so gradual that any line of separation would seem to be purely arbitrary. Indeed it might seem as if any lines, dividing a system of strata that have resulted from a process of continuous deposition under very gradually changing conditions, must be more or less arbitrary. In the Sioux river region the Niobrara beds, however, stand out distinctly and sharply defined from all the rest both lithologically and micropaleontologically, and if divisions are recognized, these must rank as a separate formation. The features that distinguish this group of strata from the Dakota-Benton below and the Pierre above depend upon the fact that when the subsidence that affected the bottom of the Cretaceous sea and the adjacent shores was at, or below, a certain stage, mechanical sediments failed, and the absence of such sediments favored the enormous expansion of certain types of microscopic life endowed with power to protect their soft protoplasmic bodies with shells of carbonate of lime. The dead skeletons of successive generations of such organisms, unmixed with the grosser products of land erosion, constitute practically the only sediments that accumulated during the Niobrara phase of the Cretaceous. It is upon the nature of these skeletons and their mode of aggregation that the very unusual characteristics of the rocks belonging to this particular stage depend.

CHARACTERS OF THE DEPOSITS IN DIFFERENT LOCALITIES COMPARED.

As has already been said, the Niobrara deposits are not uniformly chalky; neither have they had everywhere exactly the same origin. They differ in these respects at different localities, and, to some extent, at different levels in the same exposure. Along the Sioux river certain portions of the formation consist of thin-bedded, brittle, shelly limestones with chalky partings between the laminæ. In such cases the crowded valves of *Inoceramus problematicus* leave no doubt as to the principal source of the material composing the strata. Near Ponca, Nebraska, the Inoceramus-bearing beds are more compact than on the Sioux, and they are associated with heavier and more typical beds of chalk. A little farther up the Missouri, at Saint Helena, there are no Inoceramus beds. Traces of occasional valves may be found here and there in the uniformly massive layers that rise one above the other in a vertical wall of almost snowy whiteness; but there is nothing correspond-

ing to the immense aggregations of individuals that we find farther east. There are some small colonies of *Ostrea congesta* but, on the whole, mollusk shells make up a very insignificant part of the deposit The thickness of the chalk at this point is about 90 feet, and it rests on a foundation of Benton shales that rise to a height of 40 feet above the level of the water in the river. From Saint Helena to the mouth of the Niobrara, the exposures of chalk on both sides of the Missouri present about the same general appearance. At Yankton, South Dakota, the chalk is used on a large scale in the manufacture of Portland cement. The beds worked for this purpose, embracing a thickness of about 60 feet, lie geologically above those seen at Saint Helena, but there are no essential differences in macroscopic characters to be noticed.

PALEONTOLOGY OF THE CHALK.

It is aside from the purpose of this paper to discuss the general paleontology of the chalk, in the region we are describing, with any approach to fullness. A few general statements, indicating in a broad way the biological relations of the deposit, are all that can be undertaken. Vertebrate remains are not common, and the few that are known belong to fishes. The sharks were represented by the genera Ptychodus, Otodus and Lamna, and of each there are indications of but a single species. Bony fishes were present, but by no means numerous. Among invertebrates the only forms at all conspicuous are *Inoceramus problematicus* and *Ostrea congesta*. The former flourished best in the eastern half of our area, the Ostrea is most common west of Ponca. But while forms large enough for macroscopic study were comparatively few in number both as to individuals and species, microscopic life of wonderful beauty and of the highest scientific significance was developed in incomprehensible profusion. The characteristic faunas and the floras of the Niobrara must be studied with the microscope.

HESITANCY OF AMERICAN GEOLOGISTS TO RECOGNIZE THE NIOBRARA DEPOSITS AS CHALK.

Before discussing the microscopic life of the Niobrara age, it may be worth the while to notice an interesting mental attitude of leading American geologists to the question of the existence of chalk on this side of the Atlantic. Notwithstanding the fact that the earliest travellers up the Missouri river, and every one

who has since followed in their footsteps, must have been convinced that the beds in question present, outwardly at least, all the physical characteristics of chalk, and notwithstanding the further fact that Professor Bailey pointed out the foraminiferal origin of the material as long ago as 1841, there yet grew up a very firmly-rooted notion that the peculiar earthy material we call chalk is not found in any of the geological formations of this continent. For example, Professor Dana, in the second edition of his Manual, speaks of the beds of sand, marl, and loosely aggregated shell limestone in the Cretaceous strata of America, but he adds with intentional emphasis that "they include in North America *no chalk*." In the third edition of the Manual the statement is modified so as to read that "they include in North America no chalk, excepting in western Kansas, where, 350 miles west of Kansas City, a large bed exists." In the second edition of Le Conte's Elements of Geology we are told that chalk occurs "nowhere except in Europe;" but in the third edition it is stated that "recently good chalk composed of foraminiferal shells, and containing flints, has been found in Texas." In the Geological Studies of Dr. Alexander Winchell, the author, after discussing chalk tells us, on page 64, that "it does not occur in America;" and the impression is thought to be worthy of repetition in nearly the same words on page 433. In the Canadian Naturalist for 1874, Dr. G. M. Dawson has an article on the Cretaceous rocks of Manitoba,[1] in which, referring to the Cretaceous of America in general, he says that "this formation contains no beds of true chalk." At the meeting of the Association of American Geologists in April, 1841, Nicollet gave an account of the geology of the regions covered by his explorations along the Upper Mississippi and Missouri. In this account the Cretaceous strata along the Missouri are noticed, and the statement is made that no true chalk or flint was observed. Lyell also encourages the notion that there is no chalk in America; but it will not be necessary to make further quotations in illustration of the attitude referred to.

While some of the leaders of geological thought on this side of the water have been slow to acknowledge the presence of chalk in the American Cretaceous, the plain people who are not geologists, not governed by conventionalities nor influenced by authorities,

[1] Note on the occurrence of Foraminifera, Coccoliths, etc., in the Cretaceous Rocks of Manitoba, Canadian Naturalist, Vol. VII, No. 5, 1874.

have never hesitated to call the material composing certain parts of the Niobrara deposits "chalk." At Saint Helena, Yankton, and wherever, indeed, the formation outcrops in massive layers, the material is constantly referred to as "chalk," "chalk-rock," or "chalk-stone." The use of one or another of these terms in common speech is more than fifty years old, for in 1841 Professor Bailey received from the far Northwest a sample of what was locally known as "prairie chalk."[1]

WHAT IS CHALK ?

Whether the material composing the Niobrara deposits is chalk or not may depend somewhat on our definition of the term; but if in England the name is applicable to a soft, whitish, calcareous rock that accumulated on a sea bottom lying beyond the reach of mechanical sediments, and was composed of multitudes of practically entire shells of Foraminifera imbedded in an imperfectly indurated matrix of coccoliths and comminuted foraminiferal débris, then the term may be justly applied to a very large portion of the deposits of the Niobrara age along the Missouri river. For, in the first place, a very casual examination of the material would establish its physical identity with much of the English chalk. In the second place, one needs only the cheapest of compound microscopes to domonstrate that it is surprisingly rich in the most perfectly preserved specimens of Foraminifera that in a large number of cases are specifically the same as those so long known in the chalk of Europe. In the third place, a better microscope will show that every cubic inch of the Niobrara chalk contains many millions of the minute circular or elliptical, disk-like bodies called coccoliths which cannot be distinguished from similar bodies occurring in similar numbers and in similar relations in typical chalk on the other side of the Atlantic.

SOME REFERENCES TO LITERATURE IN WHICH EITHER THE CHALKY CHARACTER OR FORAMINIFERAL ORIGIN OF THE NIOBRARA DEPOSITS IS RECOGNIZED.

In view of the widely prevalent impression that the American Cretaceous contains no chalk, some references to the literature in which the chalky character or foraminiferal origin of the beds in question is recognized may not be without interest. In the Amer-

[1] Amer. Jour. Sci. and Arts, first series, Vol. XLI, p. 400, 1841.

ican Journal for 1841[1] Prof. J. W. Bailey describes the sample of "prairie chalk" already noted as being very rich in beautiful forms of the "elegantly little." The "elegantly little" are Polythalamia (Foraminifera) and of these he gives four excellent figures which, although unnamed, are readily recognized as common species composing a large proportion of typical chalk, whether we collect it in England or along the Missouri river. In the same note it is stated that Professor Bailey has also found very interesting forms of Polythalamia in the specimens collected by Mr. J. N. Nicollet from the "far west."

In 1843 Ehrenberg published his Memoir on the Extent and Influence of Microscopic Life in South and North America. Most of the work is devoted to diatoms and desmids, but a few pages are given to the discussion of Foraminifera, including forms from the Cretaceous chalks and marls along the Missouri river. The abundance of foraminiferal species and the identity of some with species occurring in the chalk of Europe are among the facts established.

An extended notice of Ehrenberg's memoir by Professor Bailey was published in 1844.[2] Copious extracts from the memoir are incorporated in the notice, and in a foot-note there is a figure of what is supposed to be *Textularia americana*. A year later there is another paper by Professor Bailey, which appears in the 48th volume of the same journal, and in the course of which the author says, concerning Foraminifera in specimens from the Missouri river, that "they are remarkably abundant and beautifully preserved."[3]

Between 1853 and 1861 Meek and Hayden worked out the succession of Cretaceous strata along the Missouri. Numerous papers were published under the joint authorship of the geologists named. The chalk of the Niobrara is frequently mentioned, sometimes as "chalk marl," and sometimes as "calcareous marl weathering to a yellowish or whitish appearance above;" and in their detailed section, published in the Proceedings of the Academy of Natural Sciences, Philadelphia, December, 1861, the "calcareous marl" of Formation number 3 is said to contain "several species of Textularia."

The beds to which Professor Dana refers in his Manual as the

[1] Loc. cit.
[2] Am. Jour. Sci. and Arts, first series, Vol. XLVI, p. 297, 1844.
[3] Ibid., Vol. XLVIII, p. 341, 1845.

only known example of American chalk are doubtless the ones described by Mr. D. Collier in 1866.[1] Of the material forming these beds, which extend for a distance of over one hundred and fifty miles east and west, Mr. Collier says: "On one occasion, in company with a companion, I was able to climb to the top of a bluff of pure chalk, so soft that I could cut and carve it with the knife I carried in my belt, and so fine that it covered my clothes as thoroughly as when in my college days a classmate wiped the blackboard with my back."

In his first Annual Report of the United States Geological Survey of the Territories, Dr. Hayden takes occasion to say concerning the Niobrara division of the Cretaceous: "Its principal character is a gray or light yellow chalky limestone; much of it so pure as to make a good chalk for commercial purposes."[2]

In 1870 Dr. Charles A. White, in discussing the Inoceramus beds along the Sioux river, which are in Iowa the equivalent of the Niobrara of Meek and Hayden, tells us that, among other fossils, "minute Foraminifera (probably Globulina) are sometimes met with in great numbers."[3]

The article by Dr. G. M. Dawson, already cited as appearing in the *Canadian Naturalist* for 1874, marks a very important step in advance of all previous publications in the matter of investigating the origin and composition of the Niobrara chalk. The strata of Manitoba that were the subject of investigation are the northward continuation of the chalk beds of our Sioux river region, and Dr. Dawson was able to compare microscopically the Manitoban with Nebraskan material. The article is illustrated with figures of Foraminifera, and speaking of this group of organisms he says: "The general facies of the foraminiferal fauna of the Cretaceous rocks of Manitoba and Nebraska singularly resembles that of the ordinary English chalk. Both abound in Textularine and Rotaline forms of similar types."

Dr. Dawson's paper, however, owes its chief importance to the fact that it is the first, so far as I know, that recognizes coccoliths as agents in the formation of American chalk. Coccoliths, in my judgment, are much more characteristic of chalk than Foraminifera. Individually they are thousands of times more nu-

[1] Am. Jour. Sci., second series, Vol. XLI, May, 1866.

[2] First Ann. Rep. of the U. S. Geol. Survey of the Territories, embracing Nebraska, by F. V. Hayden, U. S. Geologist, p. 54, 1867.

[3] Geology of Iowa, Dr. C. A. White, Vol. I, p. 294, 1870.

merous, and collectively they make up a much larger proportion of the bulk of true chalk than do the larger and more obtrusive foraminiferal shells. Chalk composed of Foraminifera, either broken or entire, is harsh and rough and unsuited to many purposes to which this substance is applied. Coccoliths on the other hand rarely exceed the one hundredth of a millimeter in diameter, and chalk formed out of such minute bodies is soft, works smoothly on blackboard or chalk line, and may be ground between the fingers to an impalpable powder. Dawson's paper is illustrated with a number of figures showing the characteristic appearance of coccoliths under a high amplification, and along with the coccoliths there are illustrations of a number of the minute, calcareous, rod-like objects to which the name rhabdoliths has been applied. Relatively speaking, rhabdoliths are not common in the beds we are considering. They have contributed only a small percentage of the bulk of the material making up the deposit. It must be said, however, that the paper under consideration has the further distinction of being the first to announce the presence of these interesting and curious structures in the fossil condition.

In Texas, Professor Hill recognizes two chalk horizons, one in the Lower Cretaceous, the other in the upper series of the same system. We are only concerned here with the chalk of the Upper Cretaceous, for that alone corresponds in age to our Sioux river beds. That this formation abounds in Foraminifera such as Textularia and Globigerina, and that it is in reality chalk, Professor Hill urges with pertinent force in a number of publications;[1] and it is to the writings of Hill that Professor Le Conte refers when he acknowledges the presence of true chalk in Texas.

Hill's work on the geology of Arkansas[2] is the subject of an admirable review by Professor Marcou,[3] in the course of which Marcou calls attention to his discovery of *true chalk* near Sioux City (Iowa) and in Nebraska in 1863. Speaking of his paper on the Cretaceous formations in the vicinity of Sioux City, etc., read before the Geological Society of France in 1866, Marcou says: "I took the precaution to carry with me pieces of rough chalk taken

[1] Ann. Rep. Geol. Survey of Arkansas, Vol. II, for 1888. Check List of Invertebrate Fossils from Cretaceous Formations of Texas, 1889. Annotated Check List, etc., Bulletin No. 4, Geol. Survey of Texas, 1889. Foraminiferal Origin of certain Cretaceous Limestones, etc., Am. Geologist, Sept., 1889. Geology of parts of Texas, etc., Bulletin Geol. Soc. Am., March, 1894.

[2] Report cited.

[3] American Geologist, Vol. IV, p. 357, Dec., 1889.

near Sioux City, and I drew on the blackboard with them the three sections that accompany the paper."

Professor S. W. Williston, in 1890, announced that the chalk of Kansas "appears to be wholly composed of organic forms very readily visible under a comparatively low power (a one-fifth or a one-sixth objective and a C eye-piece)[1]." The forms seen by Professor Williston are the minute coccoliths and rhabdoliths which Dr. Dawson so well described in 1874, and at the time of writing the note under consideration the comparatively large Foraminifera, which may be seen with a good pocket magnifier, seems to have been overlooked. A few months later, however, Williston renewed his observations on the chalk of Kansas, and his report of these later investigations contains the statement that "the deposit seems wholly formed of coccoliths, rhabdoliths and Foraminifera, with, perhaps, radiolarians and sponges.[2]"

The foregoing references selected from the mass of literature appearing between September, 1841, and March, 1894, while incomplete as a bibliography relating to the physical characteristics and foraminiferal origin of American chalk, may yet help to make clear the successive steps whereby geologists have been led from complete skepticism regarding the presence of chalk on this side of the Atlantic to the conviction that considerable portions of the Niobrara beds along the Sioux and Missouri are, in all the particulars relating to composition and origin, identical with the chalk of Europe.

COMPOSITION OF THE NIOBRARA CHALK IN THE SIOUX RIVER REGION.

The characteristics of the Niobrara chalk are such that exhaustive investigations with the microscope may be carried out with very little difficulty. In thin sections from selected typical beds the unbroken shells of Foraminifera are very conspicuous. They lie in close proximity to each other, and their inflated chambers, filled with crystals of calcite, sometimes occupy more than one-third the area of the entire field. It is certain that more than one-fourth and in some instances probably one-third of the volume of the chalk is composed of foraminiferal shells still practically entire.

[1] Chalk from the Niobrara Cretaceous of Kansas, Science, Vol. XVI, p. 249, Oct., 1890.

[2] Proc. Kansas Acad. Sci., Vol. XII, p. 100, 1891.

The matrix in which the shells are imbedded is made up of a variety of objects, the most numerous, and the most conspicuous under proper amplification, being the circular or elliptical calcareous disks known as coccoliths. The small rod-like bodies to which the name rhabdoliths has been applied are not very common, although their presence is easily detected with a moderately high power objective.

Mingled with the coccoliths and rhabdoliths are numerous fragments that are evidently the débris resulting from the comminution of foraminiferal shells; while standing out conspicuously amid the remains of these minuter organisms are comparatively large calcareous spicule-like bodies, which, on investigation, turn out to be the disassociated rods that made up the external prismatic layer of shells of Inoceramus. This outer layer in *Inoceramus problematicus* seems invariably to have become detached from the inner nacreous layer, and, almost without exception, it has become completely disintegrated into its constituent prisms. And so it happens that, in the Inoceramus-bearing beds of the deposit, the soft matrix in which the only remaining portions of the shells, the nacreous portions, lie imbedded, is composed very largely of these rod-like prisms mingled with skeletal parts of the ordinary chalk-forming organisms. Even in the typical, massive, chalky beds that bear no outward traces of mollusk shells of any kind, these same prisms, while greatly diminished in numbers, are by no means uncommon; and so in any consideration of the constituent elements of the chalk these separated units from the external layer of valves of Inoceramus must be reckoned as no unimportant factor.

When the chalk is treated with acid there remains a small amount of insoluble matter consisting of clay, fine grains of sand, a very few minute pebbles, none of which, so far as observed, exceed five millimeters in diameter, and a small number of internal casts of the chambers of Foraminifera. Nearly all the foraminiferal shells have the chambers filled with calcite; a few have these cavities still empty or filled simply with air; but in a small number of cases the chambers were filled with an opaque, insoluble mineral, probably silica deeply stained with iron oxide, that remains as perfect internal casts after the shell has been dissolved in acid. The amount and composition of the residuum vary with the purity of the chalk. In the purer samples it scarcely exceeds one per cent; in others, of course, the percentage ranges very much higher.

THE MICRO-PALEONTOLOGY OF THE CHALK.

In all the chalk examined the Foraminifera are very numerous. Many are large, vigorous-looking specimens of the types to which they belong, and an unusual number of the shells remain perfect. They are easily separated from the finer particles constituting the matrix by carefully grinding the chalk under water in a shallow dish, decanting and renewing the water as long as gentle rubbing of the heavier residual material produces any traces of milkiness. The particular genera and species that will be found after the washing process is complete will depend somewhat on the locality from which the specimen under investigation was derived. Even at the same locality samples of chalk from different beds will be found to differ in a marked degree so far as relates to the presence or absence, the association, or the predominance, of certain types. It would be very tedious, unprofitable and altogether aside from my purpose, to give you a catalogue of the genera and species of the foraminiferal fauna. Indeed, according to Carpenter, Brady, and other authorities, species in the sense of constantly differentiated races do not exist among Foraminifera, and it is almost impossible to define genera; but some general statements, which may lead to scientific considerations of some importance, may be possible and permissible under the circumstances.

THE FORAMINIFERA, WITH OBSERVATIONS ON THEIR DISTRIBUTION.

Saint Helena, Nebraska, seems to me to be the most typical locality in the region under consideration. In samples of chalk from this locality large forms of *Textularia globulosa* of Ehrenberg are the most common and the most characteristic fossils. Here the species presents its ideal characteristics. The chambers are inflated and spherical, and the shell is robust and widens rapidly toward the larger end. This same shell, be it remembered, ranges throughout the Niobrara of America from Texas to Manitoba, and it is one of the most conspicuous forms at certain horizons in the chalk of Europe. Associated with *Textularia globulosa* is a smaller shell that is proportionately thinner and narrower and every way less robust. In some places this smaller form is the prevailing type. It has been regarded as a distinct species, and was figured by Dawson, in the paper already cited, under the name of *Textularia pygmæa*. While these two forms grade into each other

perfectly when a sufficient number of specimens is examined, it will be profitable for the present to keep them apart, inasmuch as the distribution of the two types presents some facts worthy of consideration. Recall for a moment the geographical and bathymetrical conditions of the region while the chalk was forming. The shore line of the Niobrara sea extended northeasterly from near the southwest corner of Iowa. From that shore line the sea spread away westward to beyond the Rocky mountains. The site of Saint Helena was many miles from shore, and was covered by moderately deep, clear water, unpolluted by detritus washed in from the land. It was in this pure, clear sea that *Textularia globulosa* found the conditions most favorable to its existence. Here it multiplied beyond all calculation, here the individuals show all the symptoms of normal health and vigor, and here they attain their ideal symmetrical form. As, however, we approach the shore, it becomes evident that the conditions, so far as Textularia is concerned, became more and more adverse, for the chalk from Sioux City, Hawarden, Auburn, and other points east of the Sioux river, contains but few of the vigorous forms we have noted. On an average the textularians do not attain more than half the size reached by the larger individuals from Saint Helena. At Auburn, the most easterly point at which the chalk is known to occur in place, only the smallest forms of *Textularia pygmæa* occur. In this connection there is another very striking fact worthy of notice. The textularians from the more easterly localities are often very unsymmetrical and irregular in their mode of growth. It would seem that they were not only starved and stunted, but they were frequently deformed by the unfavorable environment prevailing in regions approximate to the shore.

In some of the beds at Sioux City, which is one of the intermediate points between Auburn and Saint Helena, the diminutive forms of Textularia are very numerous, but mingled with them are a few conspicuously large individuals recalling those from the great chalk cliffs farther up the Missouri. There is one very marked difference, however, between these and the specimens from Saint Helena. Like the smaller individuals of the same region they are more or less distorted. What is more, the later formed chambers of the larger specimens often depart from the biserial type, and the shell may terminate in various irregular ways. There may be at last but a single series of cells, but it is more common to find three, four, or even five series. Sometimes groups of extra chambers protrude from the sides of the shell like unhealthy excrescences, and again the later

chambers may be simply heaped together in inextricable disorder. Everything suggests abnormal, if not positively diseased, conditions. The depauperating effects of unfavorable environment seem to have acted in three ways: first, to retard growth and thus produce the pygmæan type; second, to cause deformity by unsymmetrical growth even when the biserial arrangement is maintained; third, to interfere with the biserial arrangement of the later formed chambers among the more vigorous individuals, and to produce all possible types of departure from normal regularity.

In all the thousands of specimens examined I have seen nothing corresponding to Bailey's figure of *Textularia americana*, nor have I been able to recognize as many species as Ehrenberg described from the region along the Missouri. There are endless variations, many of which would doubtless have been formerly regarded as of specific value; but, after all, I can see no reason for regarding all the textularians of the region, with their countless variations as to size and proportions, including departures from symmetry and biseriality, as other than varieties of a single species which for the present we may call *Textularia globulosa* Ehrenberg.

While Textularia seems to have flourished best in the deeper and purer waters remote from shore, the reverse is true of another group of forms that have usually been identified with Ehrenberg's *Rotalia globulosa* or *Rotalia aspera*. According to Brady, these may all be referred to the genus Globigerina and represent a single species, the *Globigerina cretacea* of d'Orbigny. The forms in question present a wide range of variation among themselves, but the average or ideal individuals consist of one or two spirally arranged whorls of rapidly increasing globular chambers the walls of which are thin and perforated by relatively large foramina. Among the departures from the average type there are some with few, large chambers, agreeing well with *G. bulloides;* while in slides from Saint Helena there are occasional individuals in which the last chambers are curiously elongated so as to impart to the entire shell an aspect identical with Brady's species, *Globigerina digitata*. The earlier formed chambers are in all respects like those of the typical *Globigerina cretacea*, and it will be in perfect accord with biological conceptions to regard the peculiarities of the individuals in question as due to accidental variations in the form of the terminal chambers, and not as permanent characters indicating a distinct species. The young of the Globigerinæ float at the surface, but as the shells, with age, increase in size and thickness the animals sink

through the water and their minute tests become mingled with those of other species that spend their entire life in the ooze at the bottom. Now Brady's specimens of *Globigerina digitata* came from bottom dredgings. The species was never taken with the tow-net at the surface. It is probable that in each case the abnormal chambers were added after the organism came to final rest amid the bottom ooze; and it is at least possible that the abnormality noticed may be due to the fact that amid this ooze the restrictions to normal growth are very much greater than those affecting the animals when floating freely near the surface. We have seen in the deformed and otherwise abnormal textularians that the simple protoplasm making up the bodies of Foraminifera responds to changes of environment in such a way as profoundly to affect the form and proportions of the shell; and it is quite possible that, in the crowded conditions existing upon the sea bottom, some individuals were so unfavorably situated as seriously to interfere with normal, symmetrical growth. It is an interesting fact that the deformed specimens of Globigerina are associated with the vigorous symmetrical types of Textularia at Saint Helena. Nearer the shore, as indicated by the material laid down at Sioux City, Hawarden, Auburn, and other points east of the Iowa boundary, the Globigerinæ flourished in greater profusion than farther west, and evidence of distortion, or any interference with normal growth, among the multitudes of vigorous looking individuals that crowd the strata in this marginal part of the Niobrara basin, are extremely rare.

While Textularia and Globigerina are the predominant types in the region under consideration, there are other genera that show similar peculiarities of distribution. For example, a very beautiful species of Truncatulina, or probably Anomalina, is somewhat common at certain levels in the exposures at Saint Helena and Yankton, but there is not even a trace of it in the deposits east of the Sioux river. Specimens of Bulimina are not rare, and Polystomella, Cristellaria, and Frondicularia, occur occasionally at the western localities named, but farther east they are so far unknown. On the other hand, there are some genera peculiar to the region east of the Sioux, but it would scarcely add anything to the force of the facts already stated to enumerate them.

PROBABLE CAUSE OF THE DIFFERENCES OBSERVED.

Is it possible to assign any cause for the observed differences in the foraminiferal faunas of the eastern and western portions of the

Sioux river region? Remember that from the beginning of the Dakota age to near the close of the Niobrara the region was practically one of progressive subsidence. There are evidences that we cannot now discuss of numerous oscillations of level, but on the whole the tendency of the sea bottom and the adjacent lands was downward. During the culmination of the peculiar conditions characterizing the Niobrara, the sea was clear and had considerable depth, but not abysmal, over the present sites of Yankton and Saint Helena; while farther east the waters were shallower and may sometimes have been polluted by rock detritus to a slight extent during the upward phases of oscillation, or during periods of excessive rainfall. All the evidence suggests a clear peaceful sea with its bottom gradually sloping away from the shore to only moderate depths. Upon the bottom of this sea the textularians flourished, while floating near the surface were the younger individuals of the globigerine forms already noticed. Either floating in the water or resting upon the bottom were the peculiar coralline plants of which the bodies called respectively coccoliths and rhabdoliths were constituent parts.

Now, the differences noted between the textularians at Saint Helena and those at Sioux City and Auburn are in some way connected with differences in physical conditions at the points mentioned. The only differences that are readily suggested are the differences in the depth and in the amount of earthy sediments over different portions of the area.

No one can tell how such slight differences of environment would react on the simple living matter of Textularia, but that they did affect it profoundly becomes obvious upon comparing the shells of the beautiful, symmetrical, thrifty-looking specimens from Saint Helena with those of the starved, impoverished, deformed specimens from Sioux City and Auburn. In the case of the globigerine forms that during most of their lives float near the surface, the condition of the bottom was not a matter of so much moment. The water at the surface was doubtless clear enough for their purpose, for even the small amount of sediment discharged into the sea by the sluggish, nearly base-leveled streams, must have been limited to the lower strata of the water. Near the surface, too, food was doubtless even more abundant than it was at the same depth farther west, and thus it happened that near the shore the Globigerinæ flourished, and their full-grown shells, bearing every

indication of life under most favorable conditions, settled down among the unhealthy and depauperated textularians to which life had been a perpetual struggle with adverse surroundings. The shallow-water chalk contains large numbers of shells of vigorous Globigerinæ mingled with many small and deformed shells of Textulariæ, while the deep-water chalk abounds in robust textularians with relatively few Globigerinæ. Among the globigerine shells of the deeper water are a few rather remarkable monstrosities.

COMPARISON WITH ENGLISH CHALK.

An attempt was made to compare our American chalk with that of England, but the opportunities for getting the desired number of examples from abroad were not good and the results are not altogether satisfactory. Enough, however, was determined to demonstrate the presence in English chalk of the same species of Textularia and Globigerina that are so common along the Missouri; there are closely allied species of Frondicularia, Bulimina, and Truncatulina; there are also prisms from the outer layer of Inoceramus shells; while enclosing and imperfectly cementing together all the larger objects are minute, dust-like coccoliths that cannot be distinguished from those making up so large a percentage of the deposits of the Niobrara. The conclusions so long ago reached by Ehrenberg and Bailey[1] as to the identity of European and Missouri river chalk seem to be fully established. The water in which the English chalk was deposited was probably deeper than the Niobrara sea between the present site of Yankton and the eastern shore, somewhere near the middle of Iowa. Neither sea was necessarily very deep. As to our Sioux river area of deposition I conceive that the lands draining into it had subsided practically to base level, and that therefore chalk may have been deposited within a few miles of shore. The singular absence of corals, sea-urchins, and all the higher forms of marine invertebrate life, except one species of Inoceramus and one of Ostrea, requires explanation, but at present there is none to offer. The seas of the English chalk were somewhat richer in respect to such types of life than ours; but, compared with many other seas, their striking poverty in all but lowly organized microscopic forms must be acknowledged.

[1] Reports of the First, Second and Third Meetings of the Association of American Geologists and Naturalists, p. 357, 1843.

The practical identity of conditions in the two widely separated regions we have been comparing remains a fact of much scientific interest. While, in the forms of coccospheres and Foraminifera, the lowly and the obscure of earth's organic hosts were revelling in peaceful and unpolluted seas in the longitude of the first meridian and contributing their dead skeletons to form the chalk of Europe, far away to the west, beyond the 90th meridian, more than a quarter of the way around the globe and separated from the first area by an abysmal ocean and a continental mass of land, there was another clear sea with low flat shores in which the same or very similar humble types of life were contributing material to form the chalk beds of Iowa, South Dakota and Nebraska.

PAPERS READ.

QUATERNARY TIME DIVISIBLE IN THREE PERIODS, THE LAFAYETTE, GLACIAL AND RECENT. By WARREN UPHAM, 86 Newbury St., Somerville, Mass.

[ABSTRACT.]

ACCORDING to definitions in text-books by Dana, Archibald Geikie, and Etheridge, the Quaternary era began with the change from the mild Pliocene climate to that of the Glacial period, with its accumulation of vast sheets of land ice in high latitudes, and has continued to the present time. We are living in the Quaternary era, as thus defined, and it must extend far into the future to be at all proportionate in length with the previous co-ordinate divisions of geologic time. LeConte and Prestwich, however, consider the Quaternary division of time as completed at the dawn of civilization, with traditional and written history; and they assign recent geologic changes to a new era, named by LeConte the Psychozoic, which is separated from the preceding principally on account of the supremacy of man. The former view seems preferable because man is known to have been contemporaneous with the Ice age.

Quaternary time therefore is here assumed to include (1) the period of changed conditions causing the accumulation of the ice-sheets; (2) the Glacial period, when the glacial and modified drift were formed; and (3) the Post-glacial, Recent, or Present period, extending from the departure of the ice-sheets until now. The first and second of these periods, which were comparatively long, constituted the Pleistocene division, while the third and very brief period is the Present or Psychozoic division, of the Quaternary era.

The Lafayette period. — The broad lower part of the Mississippi valley, from the southern boundary of the glacial drift to Louisiana, contains a very extensive, unfossiliferous deposit of sand and gravel, designated formerly from its prevailing ferruginous color as the Orange sand, later called by McGee the Appomattox formation in its development on the coastal plain of the Atlantic and Gulf States, but recently named the Lafayette formation from Lafayette County in northern Mississippi, where it was earliest discriminated by Prof. E. W. Hilgard in 1855 and 1856. This formation was spread across the valley plain 50 to 150 miles or more in width along an extent of 600 miles from the mouths of the Missouri and Ohio rivers to the Gulf of Mexico, during the closing stage of the Tertiary era and the beginning of the Quaternary, to each of which it has been assigned. McGee, Chamberlin, and Salisbury hold that it is probably referable to the Pliocene period; while Spencer, Hilgard, E. A. Smith

and others, as it seems to me preferably, consider it as the earliest of our Pleistocene formations. Its northern continuation beneath the glacial drift is recognized by Salisbury in western Illinois to a distance of a hundred miles northward from the Missouri River and boundary of the drift, and gravels believed by him to be probably of the same formation occur in the Wisconsin and Minnesota driftless area, while northeastward he has observed the Lafayette gravels in the Ohio valley in southern Indiana about 150 miles from the Mississippi. McGee states that the Lafayette beds attain their maximum thickness, which is 200 feet or more, in the region about the mouth of the Mississippi, and that they vary thence to a thin veneer, the thickness being proportional directly with the volume of neighboring rivers, and inversely with the extension inland.

Previous to the maximum advance of the ice-sheet, the Mississippi River and all its large tributaries eroded deep and broad valleys through the Lafayette formation and underlying strata, cutting at New Orleans to a depth at least 760 feet below the present sea level. Along the central valley, from Cairo to the Gulf, this erosion averages probably 200 feet in depth upon a belt 500 miles long, with a width of 50 to 100 miles, excepting isolated plateau remnants of the Lafayette and older beds, of which the largest are Crowley's and Bloomfield ridges, in Arkansas and Missouri. The land during the valley erosion was certainly 760 feet higher than now, but this I think to be only a small fraction of its uplift. From the transportation of northern Archean pebbles and cobbles of crystalline rocks to the Lafayette beds of the lower Mississippi and of Petite Anse Island, on the Gulf shore, in the direct line of the axis of the Mississippi valley, Hilgard believes that during the deposition of these beds the valley had a greater descent and stronger currents of its river floods. He suggests that the increased altitude of the interior of the continent needed to give these formerly more powerful currents may have been 4,000 to 5,000 feet, being sufficient, probably, to bring the cold climate and ice accumulation of the Glacial period.

Marine submergence of the low coastal and Mississippi valley areas occupied by the Lafayette formation is supposed by McGee and Spencer to have been requisite for the deposition of its sand and gravel beds, but they see that immediately afterward the land was much higher than now to permit the extensive and deep erosion of that time. A simpler view of the epeirogenic movements, closing the Tertiary era and inaugurating the Quaternary, seems to me to be found in ascribing these beds to deposition on land areas by flooded rivers descending from the Appalachian mountain region and from the Mississippi Basin, spreading gravel, sand, and loam over the coastal plain and along the great valley during the early part of a time of continental elevation. The land had lain during the long Tertiary periods at lower altitudes, and its surface was largely enveloped by residual clays and by alluvial sand and gravel. With the elevation of the continent, increased rainfall and snowfall and resulting river floods swept away these superficial materials from the higher lands and spread them on the coastal plain and along the Mississippi valley, where the streams expanded over broad areas with shallow and slackened currents. As the elevation increased, however, the rivers would attain steeper slopes, and finally erode much of the deposits which they had previously made. During the culmination of

the uplift, which the writer believes to have been the chief cause of the Ice age, Chesapeake and Delaware bays were excavated, and erosion was in progress at a far more rapid rate than with the present low altitude of this region.

The Lafayette formation seems to me more closely related to the Glacial period and the conditions producing the ice-sheets than to the preceding very long Tertiary era, and for the same reasons which have been well stated by Hilgard and Spencer, namely, their dependence alike on the epeirogenic elevation.[1] With the Ice age, we should unite this probably much longer preglacial time of gradual uplift of the continent, and the Postglacial or Recent period in which we live, to form together the three successive parts of the Quaternary era. How long the early part comprising the epeirogenic uplift, represented by the deposition and erosion of the Lafayette formation, may have been, we can only vaguely or perhaps approximately estimate. During the beginning of the uplift its effect would be probably to increase the transportation and deposition of gravel and sand by the rivers many times beyond their present action. The rate of average land erosion now prevailing throughout the drainage area of the Mississippi is supposed by McGee to be competent to supply in about 120,000 years a volume of river gravel, sand, and silt equal to the original Lafayette formation in the Mississippi valley. With the greater altitude and increasing slopes of the land during the deposition of the Lafayette beds it may have required a third or a sixth of the time here mentioned, that is, some 40,000 or 20,000 years. As the elevation continued, however, rapid fluvial erosion of these deposits and of the underlying strata ensued, which was extended over so long and broad an area of the lower Mississippi valley, and to such depth, that, even with the high continental elevation of 2,000 to 3,000 feet known from submerged valleys off both the Atlantic and Pacific coasts, it must have required a long epoch. Perhaps it may be reasonably estimated twice as long as the time of the deposition, or somewhere between 40,000 and 80,000 years. The Lafayette period thus comprised two parts or epochs, the first characterized by the deposition of the formation, the second by its extensive erosion and the culmination of the continental uplift.

The Glacial period. — Comparison of the work of the glaciers and ice-sheets of the present time with those of Pleistocene time seems to me best accordant with a reference of all our glacial drift to a single continuous period of glaciation, which, though occupying probably 20,000 years or more, was yet brief as compared with the duration of most other recognized geologic periods or epochs. The outflow of the upper part of the Pleistocene ice-sheets probably exceeded the currents of narrow Alpine glaciers, but was less than the advance of broad and deep polar glaciers which end in the sea. For the journey of Pleistocene boulders 1,000 miles in the ice-sheet, somewhat less than 3,000 years would be

[1] That epeirogenic movements of land elevation caused the accumulation of the Pleistocene ice-sheets, and conversely, that the end of the Glacial period was due to land depression, I have shown in an appendix of Wright's "Ice Age in North America," 1889, pp 573–595; the Am. Geologist, vol. vi., pp. 327–339, Dec., 1890; and the Am. Jour. of Science, III, vol. xli., pp. 33–52, Jan., 1891; and same, vol. xlvi., pp. 114-121, Aug., 1893. This view, which may be called the epeirogenic theory of the causes of the Ice age, has been gradually thought out in America by Dana, LeConte, Hilgard, Wright, and others, and in Scotland by Jamieson. Its earliest announcement was in 1855 by Dana in his Presidential Address before this Association (Proc. A. A. A. S., vol. ix., for 1855, pp. 28, 29; Am. Jour. Sci., II, vol. xxii., pp. 328, 329, Nov., 1856.)

required if the average of the glacial currents was five feet per day. The amount of the glacial erosion and of the drift, when compared with the erosion by the Muir glacier in Alaska, imply a short rather than a long duration of the Ice age. This conclusion is further affirmed by the continuance of the same species of the marine molluscan faunas from the beginning of the Glacial period to its end and to the present day.

The duration of the Ice age, if there was only one epoch of glaciation, with moderate temporary retreats and readvances of the ice-border sufficient to allow stratified beds with the remains of animals and plants to be intercalated between accumulations of till, may have comprised only a few tens of thousands of years. Professor Prestwich estimates that the severely cold epoch when the ice-sheets were formed and extended to their maximum area may have been some 15,000 to 25,000 years, and that the time of final melting and departure of the ice was probably 8,000 to 10,000 years or less.

Very gentle currents of broad river floods in the Missouri and Mississippi valleys deposited the North American loess, attending the maximum extension of the ice-sheet, and accompanying its departure up to the time of formation of the great marginal moraines. The loess thus testifies that previous to the farthest glacial advance the land sank to its present altitude, and probably somewhat lower on the area of the early drift, but not to the sea level. The vast weight of the continental glacier seems to have been the chief or only cause of this subsidence, as was first pointed out by Jamieson for the similar depression of the British Isles and Scandinavia at the time of final melting of the European ice-sheet. The explanation of this continuance of the ice accumulation and advance after the depression of the land began, and until the maxima both of the land subsidence and ice extension were attained, with a low altitude and even less descent of the lower Mississippi than now, has been well given by LeConte. The subsidence was doubtless slow, even though probably many times faster than the preceding uplift. It may have occupied only 5,000 years, being at a yearly rate of a half a foot to one foot; but possibly it was two or three times as long. While the slow sinking of the land was taking place, the accumulation of the ice by snowfall may have proceeded at a somewhat more rapid rate, so that the thickness of the ice-sheet and the altitude of its surface were increasing up to a maximum nearly coincident with that of the subsidence. Finally, however, the subsidence brought a warm climate on the southern border of the ice, causing it to retreat, and giving to it in the region of the marginal moraines a mainly steeper frontal gradient and more vigorous currents than during its growth and farthest extension.

The time of general retreat of the ice-sheet in North America, with low altitude of the land and marine submergence of the coastal borders of northeastern New England, northward from Boston, and of the eastern provinces of Canada, with ingress of the sea along the valleys of the St. Lawrence and Ottawa rivers and the basin of Lake Champlain, has been named by Dana the Champlain epoch. It was the final stage of the Glacial period, and was characterized by the rapid deposition of the glacial and modified drift, whose materials had been contained in the lower part of the ice-sheet.

The Postglacial, Recent, or Present period. — Closely following the deposition of the modified drift as wide and deep flood-plains in the principal river valleys

draining away from the departing ice, these beds were deeply eroded by the streams as soon as the ice-front had so far receded that the supplies of water and drift from its melting ceased. Much of the valley drift was soon removed by the river channelling, and its remnants, being left as terraces on the sides of the valleys, caused this stage of the Postglacial period to be long ago named by Dana the Terrace epoch. In less vigorous action the streams have continued at the same work to the present day, so that this term may be extended also to comprise this whole period.

From a wide range of concurrent but independent testimonies, through the observations and computations of N. H. Winchell, Gilbert, Andrews, Wright, Emerson, Russell, James Geikie, Prestwich, Mackintosh, Logan, Bell, Hansen, and others, we may accept it as practically demonstrated that the ice-sheets disappeared only 6,000 to 10,000 years ago. Within this period are to be comprised the successive stages of man's development of the arts, from the time when his best implements were made of polished stone through the ages of bronze, iron, and finally steel, to the present time, when steel, steam, and electricity seem to bring all nations into close alliance.

Estimated Duration of the Quaternary era. — Arranged in chronologic order, we have derived for the three parts of the Quaternary era, as here defined, the following estimates of their duration: the Lafayette period, or time of preglacial epeirogenic elevation, with the deposition and erosion of the Lafayette beds, some 60,000 to 120,000 years; the Glacial period, regarded as continuous, without interglacial epochs, attending the culmination of the uplift, but terminating after the subsidence of the glaciated region, 20,000 to 30,000 years; and the Postglacial or Recent period, extending to the present time, 6,000 to 10,000 years. In total, the Quaternary era in North America, therefore, has comprised probably about 100,000 or 150,000 years, its latest third or fourth part being the Ice age and subsequent time. The Tertiary era appears by the changes of its marine molluscan faunas to have been vastly longer, having comprised perhaps between two and four million years, of which the Pliocene period would be a sixth or eighth part, thus exceeding the whole of the ensuing era of great epeirogenic movements and resulting glaciation.

THE NATIONAL DOMAIN. By F. H. NEWELL, U. S. Geological Survey, Washington, D. C.

[ABSTRACT.]

THE United States owns about one-third of its total area, excluding Alaska. Most of this land is now open to settlement under the homestead law, but actual occupation of the land proceeds slowly, owing to the difficulty of creating farms on this land. These difficulties are of various kinds, resulting mainly from climatic conditions, and to a less extent depending upon geologic and topographic peculiarities.

The vacant public lands are to be found to a small extent in the Southern States and those of the Mississippi valley, notably in Arkansas and Louisiana, but by far the greatest portion — over nine-tenths of the whole — is in the arid and subhumid region extending from about the one hundredth meridian to the

Pacific coast. The relative location and extent of these vacant lands is shown by accompanying maps and diagrams.

Settlement on the public domain in the eastern half of the country is retarded by the mountainous, rocky, or marshy character of the remaining land, while in the western half it is rendered difficult if not impossible by lack of water. The soil of the arid and semi-arid regions in many places is of extraordinary fertility, and — on the borders, at least — settlers are tempted to try their fortune in raising crops by dependence upon the scanty and irregular rainfall. Success is, however, attained only perhaps one year in four or five, and as a consequence great hardship and even suffering ensues along the debatable ground separating arid from humid regions. Notwithstanding these discouragements, owing to the pressure for homes, this vacant land is being taken up by the continually recurring tide of immigration. The rate of disposal in various States and territories is exhibited by the diagrams.

[This paper will be printed in the National Geographic Magazine.]

WATER RESOURCES OF THE UNITED STATES. By Prof. J. W. POWELL, Bureau of American Ethnology, Washington, D. C.

[ABSTRACT.]

THE ultimate development of the United States rests largely upon the most thorough utilization of the water resources. This is conspicuously true of the vast arid and sub-humid regions extending from the great plains to the Pacific coast. There the almost boundless extent of fertile land cannot be utilized for agriculture without the artificial application of water. The sources of supply, however, are limited, and great skill and forethought must be shown in order to employ these to the best advantage in the creation of the greatest possible number of homes for the people. In older, better settled parts of the United States the water resources are of hardly less importance for power, and municipal and domestic supply. In all cases, however, whether in arid or humid regions, the proper solution of the problem rests upon a correct knowledge of the distribution and fluctuation of the available waters. This study has been begun by the United States Geological Survey, and is now being carried on. Among the first of the general results is a preliminary map of the *run-off* prepared in a form similar to that of the ordinary map of mean annual rainfall. This run-off map, however, shows the depth in inches on the surface of that part of the precipitation which during the year flows in the streams.

[To be printed in the National Geographic Magazine.]

NOTES ON THE ATLANTIC MIOCENE. By WILLIAM H. DALL, Smithsonian Institution, Washington, D. C.

[ABSTRACT.]

I. On the Miocene of Gay Head, Martha's Vineyard.

Describing the fauna briefly, and pointing out its probable place in the scale

of miocene horizons of the Atlantic coast, also indicating the presence of Pliocene.

II. On the age of the Phosphatic Nodules of South Carolina.

Enumerating the views heretofore held in regard to these rocks, describing the fauna found in them, and pointing out their horizon to be Miocene.

[This paper will be printed in the American Journal of Science.]

A NEW FOSSIL LIRIODENDRON FROM THE LARAMIE AT WALSENBURG, COLO., AND ITS SIGNIFICANCE. By Dr. ARTHUR HOLLICK, Columbia College, New York, N. Y.

[ABSTRACT.]

THE genus *Liriodendron* is a unique monotypic genus at the present day, containing the single species *L. tulipifera*, our well-known "tulip-tree." In the past, however, the species were numerous and as diverse in the shapes of their leaves as are the oaks of to-day. They have been recorded from middle cretaceous and tertiary horizons, and we now have a well-defined new one from an intermediate horizon, the Laramie. It was found in a quantity of material sent to the late Dr. J. S. Newberry for determination, and was by him evidently recognized as a new species, and labelled *Liriodendron alatum* n. sp. It has not been described, and is now shown for the first time. The emarginate apex which characterizes the living *Liriodendron* and its ancestors is present, and there is, in addition, a peculiar winged appendage extending from the base of the leaf down both sides of the petiole. This appendage may have its analogue in the stipules which are such conspicuous features of the young shoots of the tulip-tree, but which soon drop off and disappear. On the theory that the individual development is the epitome of the development of the type the significance of these appendages is manifest.

Specimens and charts were used to illustrate the paper.

[This paper will be printed in the Bulletin of the Torrey Botanical Club, and eventually be included in a work now in preparation on the later extinct floras of North America for the U. S. Geological Survey.]

A MINIATURE EXTINCT VOLCANO. By W J McGEE, Bureau of American Ethnology, Washington, D. C.

[ABSTRACT.]

THE soda lakes of Nevada are situated in Carson desert (or Carson-Humboldt valley), in central Nevada. They are near the centre of one of the most extensive inter-montane valleys of the Great Basin. They have been described by Russell and others in their relation to the Pleistocene history of the region, but have never received especial attention as volcanic phenomena.

The larger lake, something less than a mile across, occupies a crateriform depression with raised rim; the walls of the depression show two lacustral deposits corresponding with the prevailing Pleistocene formation of the Lahonton Basin; the older deposit is slightly tilted, faulted, and metamorphosed;

and in both there are "bombs" of still more metamorphosed Pleistocene materials, lying in depressions in the strata. From these and other features it is known that the depression is a veritable crater, and produced by an explosive eruption. Furthermore, the phenomena prove that two eruptions occurred at widely separated periods. Detailed study shows that each eruption occurred near the close of a lacustral epoch, but limited deposition following each. Thus the volcanic history is intimately connected with the lacustral history, the following associations being especially suggestive: 1. Each lacustral period was accompanied by an eruption; 2. Each eruption occurred just before the end of the lacustral period, *i. e.*, when the waters were nearly subsided; 3. The lacustral accumulations were nearly equal in amount, the eruptions nearly equal in violence. These correspondences suggest equivalence in genetic sequence, and so suggest a course for the volcanism, *viz.*, the relief of pressure on the earth crust accompanying the evaporation of the waters of Lake Lahonton. While the phenomena are miniature, they are none the less significant, seem to suggest more clearly than more violent volcanism the sequential connection between unloading and extravasation.

GEOGRAPHIC DEVELOPMENT OF CHINA, KOREA, AND JAPAN. By GARDINER GREENE HUBBARD, LL. D., 1328 Connecticut Ave., Washington, D. C.

[ABSTRACT.]

EASTERN ASIA is a land of high mountains, vast plains, great rivers, and large bordering islands with good harbors, their Eastern and Southern coasts bathed by the warm equatorial Gulf Stream and long peninsulas; and these natural features have exerted a profound influence on the races of mankind who peopled this quarter of the globe. The plains are fertile and support a luxuriant mantle of vegetation; the climate is generally mild and well adapted to the development of vegetal and animal life; the bordering mountains give climatic zones favorable to the development of variety in plants and animals; by reason of the climatic and floral conditions, animal life was abundant and varied, not only on the land but in the contiguous seas and in the rivers. Thus, primitive men found the environment favorable — the climate was congenial, food abundant, the building of habitations easy, the materials for clothing accessible. Accordingly human development was rapid up to a certain stage, and the population increased wonderfully, and streams of emigration flowed in different directions toward less favored lands. But the environment and the root language was too favorable to permit the fullest development, and so at a certain stage culture stopped and intellectual progress ceased. So the culture-status of the Orient remains between the primitive and the civilized; the Oriental peoples have been left behind in the race for success; and the Oriental character is unlike that of the enlightened citizen or subject of an Occidental country. The war now waged between China and Japan, over Korea, illustrates the characteristics of the contestants; it reflects the minds of the people, the history of their development, the beginnings of mankind in that region, the natural conditions that antedated man, and, in Japan, the advance of civilization. The world affords no better example of the dependence of mankind on environment than that found in China and Japan.

A PALEOZOIC ERUPTIVE IN MISSOURI. By ARTHUR WINSLOW, St. Louis, Mo.

[ABSTRACT.]

AT the meeting of the Association in 1890, I called attention to an occurrence of pegmatite in Missouri and exhibited a few specimens of the rock.[1] Having made further study of this interesting occurrence since that time, I wish now to describe briefly the conditions under which it is found, and to add something concerning its mineralogy and origin. Special interest attaches itself to this outcrop, as it is the only one of post-Archean age found in the Mississippi valley, with the exception of the Mesozoic eruptives of Arkansas. Further, it is the only indication we have that igneous action or metamorphism accompanied the crustal movement of the Ozark uplift.

The outcrop is situated on the Camden and Laclede county lines, in the central portion of the State, south of the Missouri River, as shown in Fig. 1. The actual exposure does not exceed a few square yards, and, had it not been that the locality was prospected for lead ore, its presence might never have been detected.

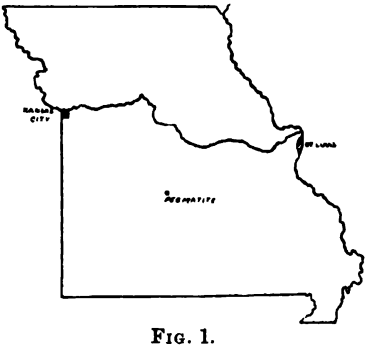

FIG. 1.

Disturbed Rocks. — The country rocks are principally lower Silurian magnesian limestones; with these are some sandstones. In this part of the State they are normally horizontal and undisturbed. Immediately about the pegmatite, however, the rocks assume abnormal and rapidly varying dips. Similar conditions have been nowhere observed within the Ozark area, and, in themselves, they are sufficient to have distinguished this locality as one of somewhat intense, though local, disturbance. These conditions are represented on the following small map (Fig. 2) constructed from a survey of the area. The short, heavy black lines represent outcrops of which the arrows show the dips.

From the map it will be seen that to the north, east, and south of the pegmatite outcrop the disturbance does not extend very far, nor are the dips excessive. To the southwest, however, the disturbance can be traced some two miles, and at points it is quite intense.

It is further noticeable that the dips are generally away from the dike, as if this were the centre of the disturbance. Exceptions to this, and steep and confused dips at other localities, such as those marked A, B, and C, suggest that there were other centres also, and that eruptive rock may exist here, not far beneath the surface.

Mineralogy. — The rocks of the dike consist of a graphic granite, or pegmatite, and of a white mica. These do not seem to be distributed or arranged in any special order, unless it is that the mica prevails near the contact with the sur-

[1] Proc. A. A. A. S., Vol. xxxix., 1890, p. 267.

rounding rocks. The dike seems to be in the form of a boss or neck which has pushed its way up through the rocks.

The structure of the pegmatite proper is part that of true graphic granite, consisting of long crystals of quartz surrounded by feldspar, sometimes it is granular. It is always fine grained, the quartz crystals not exceeding a fourth of an inch in diameter. Sometimes, masses of quartz are found with no

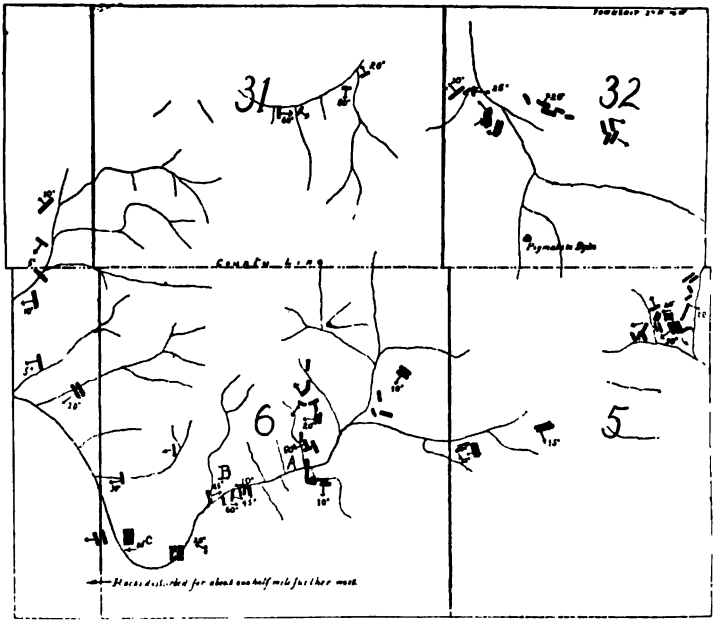

FIG. 2.

admixture of feldspar. The mica forms a rock composed of very small crystals or scales.

Professor Erasmus Haworth, who examined specimens, reports that he found only one mica, muscovite. Microline is the principal feldspar, but the acid triclinics are present in small amounts. These are probably albite and oligoclase, both or either, and, possibly, orthoclose.

The rock is much decomposed at the outcrop, being mostly soft and incoherent. No contact metamorphism of the country rocks could be detected.

Origin and Age. — The disturbed conditions of the rocks surrounding the pegmatite is in support of the view that the rock was originally molten, and that it was intruded. That it was formed by aqueo-igneous fusion, as such rocks are commonly believed to be formed, there is no reason against. That it is purely a result of segregation or alteration of rocks in situ, as has been maintained by some concerning other pegmatites, the facts are opposed to.

It is not probable that this intrusion or eruption ever reached the surface.

No traces of volcanic rocks are now found in the surrounding country, and the small size of the outcrop indicates that the present exposure is near the apex of the boss or neck.

The exact age of the intrusion cannot be determined. That it was post-lower Silurian is self-evident. We are inclined to assign it to the time of the last great uplift of the Ozarks, which was immediately after the Coal Measure epoch, and which was probably the greatest crustal movement that took place over this area.

OIL AND GAS IN KANSAS. By Prof. ERASMUS HAWORTH, University of Kansas, Lawrence, Kan.

CONTENTS.

Extent of oil and gas producing area, from Kansas City and Lawrence on the north to south line of State west of Coffeyville and Independence.
Production of oil and gas in the past.
Production of oil and gas at present.
Oil and gas producing shales and sandstones are members of the Lower Coal-Measures.
Relation of oil and gas to anticlinals and synclinals.
Original source of oil and gas the carbonaceous shales in which, or near which, they are now found.
Little inducement to penetrate the ore-bearing Mississippian formation outcropping to the east and southeast in search of oil or gas.

Extent of oil and gas producing area. — The oil and gas producing area, as now known in Kansas, extends from Kansas City and Lawrence south and southwest to beyond the southern limit of the State, covering an area of over 7,000 square miles. The western limit of the area may be approximated by drawing an irregular line from near Lawrence to a point a short distance west of Peru, or about 85 miles west of the southeast corner of the State. A small area in the southeast corner should be excluded as nonproductive, on account of the Coal-Measures being so thin. Within this area oil has been obtained principally at Neodesha, Thayer, Independence, Peru, and Paola, while gas in varying quantities has been found at Wyandotte, Kansas City, Lawrence, Paola, Ossawatomie, La Cygne, Mound City, Fulton, Fort Scott, Pittsburg, Girard, Iola, Humboldt, Thayer, Cherryvale, Neodesha, Independence, Coffeyville, Peru, and other intermediate points.

Production of oil and gas in the past.[1] — At different places within the State for many years oil, or gas, or both, have been observed escaping at the surface. In Cherokee County, a small stream was named "Tar" Creek in allusion to the escape of oil somewhere in its drainage area. Near La Cygne an escape of gas has been known ever since the early settlement of the country, and there is a semi-legendary statement to the effect that the Indians formerly held their councils around the light of the burning gas. Within the present decade, during an overflow of the Verdigris River, gas was seen rapidly escaping from the ground with sufficient force to give the appearance of boiling to the water. This resulted in the location of the present Independence gas wells. Other similar incidents could be given, for they are many, if we include cases of the escape of oil or gas from shallow wells dug here and there over the country to

[1] For a full discussion of this subject see, Hay, Trans. Kan. Acad. Sci. X. 57, 1886.

obtain water. Gas was obtained in Wyandotte near a quarter of a century ago, in Iola in 1873, and in numerous other places within the following decade. Oil was obtained at Paola in marketable quantities and in a few other places previous to the recent discoveries.

Present production of oil and gas. — Neodesha seems to be the centre of the oil producing area. The Guffey and Galey Company have been engaged in active operations for a little more than a year. A great deal of time has been spent in procuring leases and in general prospecting with the drill, so that not until within the last few weeks have they been especially trying to obtain oil in quantity. They are now pumping from a few wells at both Neodesha and Thayer, and are drilling others in what they consider the best oil territory. The production from the two places is rapidly on the increase.

The Independence wells, situated five miles southeast of Independence, across the Verdigris River, produce a small amount of oil daily, but here, gas being the desired product, the company is not trying to obtain oil. They went below several oil-producing strata, and in some instances cased off the oil in order that it might not interfere with the flow of gas.

The last gas well drilled at Iola produces small quantities of oil. As no attempt is made to save it, the drain leading from the well shows that it carries a considerable amount of oil. At Paola the wells which formerly were the heaviest producers in the State are still productive, though to a less degree. Some of them have been entirely abandoned, while others yield such small quantities that the product is sold locally for lubricating oil.

Although other eastern companies are in the field taking leases and claiming they will soon begin drilling, the Guffey and Galey Company is the only one at present actively engaged in prospecting. They have spent several hundred thousand dollars in the work, and are pushing ahead as though at least they were determined to thoroughly test the territory. Their gross expenses this season approximate a thousand dollars a day.

At the present time the cities of Paola, Ossawatomie, Iola, Humboldt, Cherryvale, Neodesha, Independence, and Coffeyville are wholly or principally lighted and heated by natural gas, while at Wyandotte, Kansas City, Fulton, and a few other places, gas is used to a considerable extent by private consumers. A conservative estimate places the cash value of the fuel and lights saved by its use at the present time at about $200,000 a year, while there is every reason to believe that in the near future it will be much greater. At Neodesha the Guffey and Galey Company use gas for generating nearly all the steam used in drilling, and have run as high as three engines at a time by direct gas pressure, letting the gas pass through the engines the same as steam.

The wells giving the strongest flows thus far drilled in the State are the Guffey and Galey wells, about four miles northwest of Neodesha. They have already produced large quantities, and the supply seems to be undiminished. Mr. Galey, who is extensively known as an oil and gas prospector of wide experience, especially in Pennsylvania, West Virginia, Ohio, and Indiana, told the writer that the Neodesha wells would be classed as about medium in Ohio or Pennsylvania. At both Iola and Cherryvale the last well bored proves to be the best one thus far obtained, and each is sufficient of itself to supply all the demands for summer use in each city.

It is an interesting and probably a significant fact that at almost every place where gas has been found the later prospectings have been the most successful. Even farther east in the coal regions, where the gas-producing formations are thin, many drill holes made in prospecting for coal have produced considerable quantities of gas, and not infrequently traces of oil as well. Further, it may be stated that scarcely a deep well has been bored in the whole territory that did not produce gas. It seems a reasonable hope that at least a third of the whole area described above is capable of producing enough gas to supply the farmers and the small villages with lights and fuel.

The oil and gas producing shales and sandstones. — The shales and sandstones in which the oil and gas are found are Carboniferous in age, and immediately overlie the lead and zinc producing Mississippian, or Subcarboniferous. Reference should be made to the accompanying section, Fig. 1, from Galena to Fredonia by way of Lowell, Neutral, Oswego, Stover, Altamont, Mound Valley, Cherryvale, Brooks, and Neodesha. The ore and chert bearing limestone is known to extend underground westward as far as Fredonia, and its surface, although irregular, has a westerly dip averaging fully 20 feet to the mile. This is abundantly proved by deep wells at Mound Valley, Cherryvale, and Neodesha, and is confirmed by similar borings at Thayer, Iola, Osage Mission, Chanute, Girard, and Pittsburg. The boring at Mound Valley did not reach the ore-bearing horizon, but went 763 feet below the surface. The distance from Lowell station is 89 miles, the elevation of the two points almost the same, so that at 20 feet dip to the mile it should be found at 780 feet. At Cherryvale a diamond drill was used making a two-inch core. The ore-bearing rock was reached at 1008 feet. The air line distance from Lowell is 46 miles, the difference in elevation is less than 30 feet, which gives a dip of 21 feet to the mile. At Neodesha it was reached at the Pierce Brothers' farm at 1068 feet. The distance is 55 miles, and after making corrections for elevations, the Mississippian is found to dip 19.5 feet to the mile. At Thayer a well on the Hite farm was sunk to 1098 feet without reaching the ore-bearing horizon, which would indicate a dip of at least 22 feet to the mile, and we do not know how much more. Detailed reports have not been obtained from Iola, but a general statement that the Mississippian was reached at about 1,400 feet indicates that here the dip is fully as great as at other places. Similarly the borings at Girard and other places named produce about the same evidence. By comparing the depth at which the Mississippian is reached at Oswego, Girard, and Fort Scott, it is found that a considerable ridge in its surface exists near Girard, probably corresponding to the surface ridge or highlands between Pittsburg and Fort Scott. This may be an anticlinal in the Mississippian limestone.

Immediately above the Mississippian is a heavy and persistent bed of shales fully 400 feet in thickness, which, in places, carries large amounts of sandstone. It seems desirable to treat these shales with the included sandstones as one formation, for the shales have remarkable persistence in extent and character, while the sandstone beds within them have just the reverse properties. Not one of them can be traced many miles in a westerly direction from its outcropping. In places sandstone rests immediately upon the Mississippian, while perhaps five miles away none can be found at that horizon, but a few score of feet above it similar or different sandstone may be abundant. Such irregularity in the

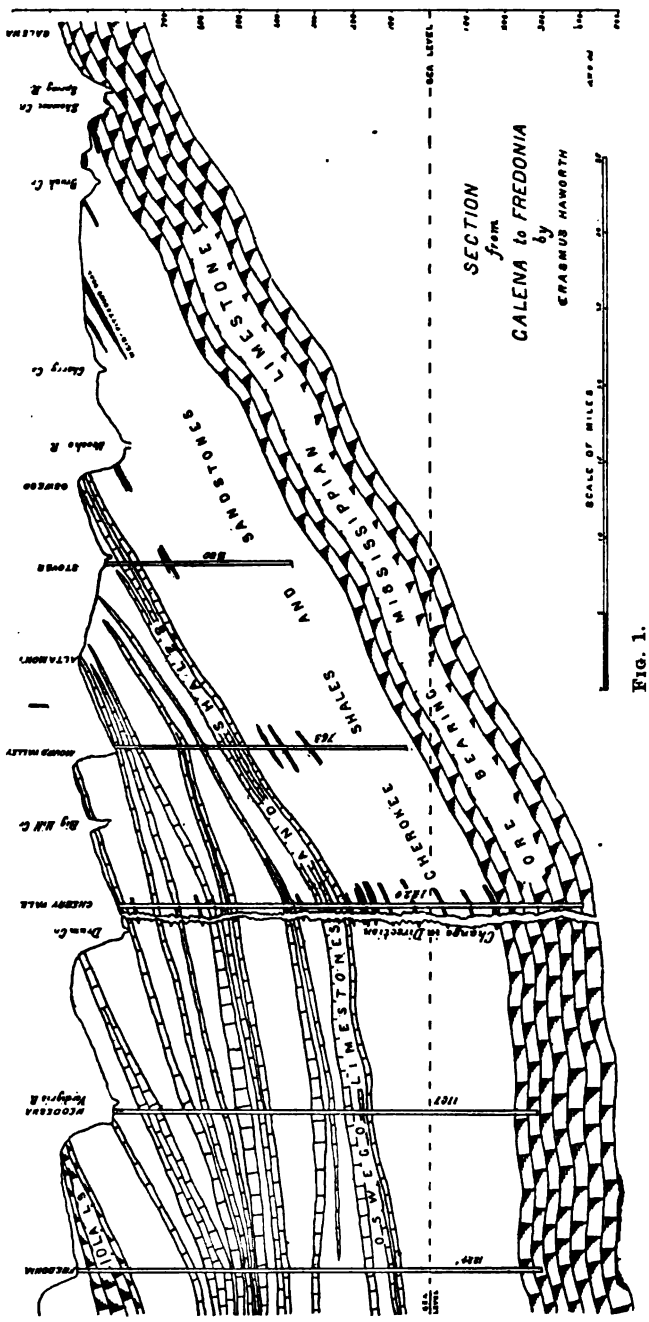
SECTION
from
GALENA to FREDONIA
by
ERASMUS HAWORTH
SEA LEVEL
SCALE OF MILES
GALENA
Shoal Ck.
Cherry Ck.
Brush R.
STOVER
ALTAMONT
Big Hill Ck.
CHERRY VALE
Drum Ck.
Neosho R.
FREDONIA
LIMESTONE
SANDSTONES
AND
SHALES
MISSISSIPPIAN
CHEROKEE
COAL BEARING
LIMESTONES
COFFEYVILLE
LOWER

Fig. 1.

sandstone is noted wherever these shales have been examined, either on the surface or by drilling. Perhaps no place could be found where a drill could pass through the entire 400 feet without meeting sandstone, sometimes at one level, sometimes at another. This great shale bed, by far the heaviest in the whole Coal-Measure formations within the State, has been called the Cherokee[1] shales, in allusion to their covering so large a portion of the surface in Cherokee County. They maintain their thickness westward to Cherryvale, Neodesha, and Fredonia northwestward as far as Iola, at least, and northward to the vicinity of Boicourt and La Cygne, and probably much farther in all directions.

From the economic standpoint the Cherokee shales are of vast importance. They contain all of the Weir City-Pittsburg coal, the Oswego coal, and the Fort Scott coal. According to the publications of Hay[2] and others it is quite probable that the Leavenworth coal is also contained within the same bed of shales. Nearly all the oil and gas of Kansas is also found within the limits of these shales, usually in the included sandstones. This is true at Neodesha and Thayer, and is principally true at Cherryvale, Coffeeville, Independence, Iola, and other places, but not entirely so. At Neodesha the principal oil sands lie near the base of the shales, while at Thayer the similar sand is found nearly 200 feet higher within the shale beds. It will thus be seen that it may be incorrect to consider the oil sand at one point the same bed of sand rock as that which is oil producing at another, although both may be included within the Cherokee shales.

First above the Cherokee shales are two limestone systems close together which are so extensive in areas covered and persistent in lithologic and palæontologic characteristics that they become exceptionally valuable as landmarks in stratigraphy. They are well exposed at Oswego, having a thickness of 10 to 12 feet each, and are separated by four feet of exceptionally black, bituminous shale. At Girard each has increased a little in thickness, but the distance between them is about the same, and is occupied by the same black shale. At Fort Scott the thickness is a little less, and the distance between them is increased to 7 feet, while the intervening shale possesses all the important characteristics of the same shale at Oswego. North of Fort Scott the formations have been traced in detail to Fulton. The lower of the two limestones is the Fort Scott cement rock, and has certain characteristics which usually render it easily recognized. The upper one is generally identified by its fossils, the coral millepora almost invariably being present in great abundance, and long, straight crinoid stems, approximating an inch in diameter and three or four feet in length being by no means uncommon. Below the cement rock at Fort Scott are three or four feet of grayish buff shale, then four feet of black shale identical with that between the limestone, and just below this the Fort Scott coal, 13 inches thick. The characteristics of these rocks are so pronounced that they can readily be recognized in the drill records to the west and north. They are found at Cherryvale, Neodesha, Thayer, and other places, and invariably are about 400 feet above the surface of the Mississippian.

It has been decided to consider the lower of these two limestone systems the upper limitation of the Cherokee shales. In various places thin limestones are

[1] Kansas University Quarterly, 2-105, 1894.

[2] Geology and Mineral Resources of Kansas; World's Fair edition, p. 86.

found below it, but none of them have persistency of extent or characteristics sufficient to justify their use for such important demarcations. The two systems combined have been provisionally named the Oswego limestone, the adjective terms "upper" and "lower" being prefixed for greater detail of designation. It may become necessary, however, in the near future to change the name, but that will be deferred until a fuller discussion can be given. It is interesting to note in passing that one of the wells at Fulton received a considerable flow of gas from this thin but exceedingly bituminous shale between the two Oswego limestones.

Above the Oswego limestones a condition is encountered which adds considerable difficulty to detailed stratigraphic work in this part of the State. A careful examination of the surface westward from Oswego to the first high hills beyond the Verdigris River reveals but five limestone systems throughout that distance, as is shown in Fig. 1. But the drill records at Mound Valley, Cherryvale, Thayer, and Neodesha, all of which agree fairly well within themselves, show the presence of nine or ten limestone systems below the fifth one in the figure. Evidently the explanation is that along with the general thickening of the different formations westward, other limestone systems have been formed which do not reach the surface eastward. The slight nonconformity thus produced seems to be confined entirely above the Oswego limestones, adding emphasis to the desirability of choosing them for the line of demarcation between the Cherokee shales and the overlying beds. Presumably the wedged-shaped formations appear at different horizons, but this cannot be said to a certainty.

The intervening shales and sandstones at different horizons above the Cherokee shales produce both oil and gas. At Independence the principal flow of oil was from sand rocks above the Oswego limestones. Just where cannot be said, as the company choose to retain detailed information on the subject. It seems that the drill passed below this, and penetrated the Cherokee shales before the heavy flow of gas was reached. At Cherryvale the earlier wells obtained their gas from the Cherokee shales and included sandstone, but later wells have been drilled farther east, on higher ground, which obtain strong flows above the Oswego limestones. One of these wells is less than 500 feet deep. At Mound Valley the principal flow of gas seems to have come from the Cherokee shales, but lighter flows were obtained above the Oswego limestones. The new oil wells at Peru, 20 to 25 miles southwest of Independence, probably have not penetrated the Cherokee shales, although detailed records have not yet been obtained. At several other places where oil or gas has been found the records have been poorly kept, or are not available in detail, so that definite statements cannot be made regarding them. It may safely be said, however, that the Cherokee shales and included sandstones are the principal oil and gas producers, but that different shales and sands of higher level are also productive. This being true, it is quite probable that their productiveness will increase westward, so that the actual depth of producing wells may not be greatly increased.

Relation of oil and gas to anticlinals and synclinals. — The details of stratigraphy are so little known that in some instances it is impossible to say whether or not there is any relation between geologic conformation and the existence of oil and gas. The general dip of all the formations is toward the west and north-

west; but along with this general dip there are many reversals of directions, and anticlinals and synclinals in other directions. Investigations this season by the different members of the University Geological Survey corps have revealed many small anticlinal ridges and synclinal troughs, usually trending parallel with the general strike of the formations, or at right angles with it. At Cherryvale the gas is obtained from beneath one of these anticlinals with axis trending at right angles to the general outcrop, or to the southeast and northwest, while the anticlinal axis itself dips to the northwest. At Neodesha the oil seems to be obtained from a synclinal trough. At Fort Scott gas was obtained from a synclinal, which possibly accounts for the failure to obtain it in sufficient quantity to be of much commercial importance. It is hoped that at the close of the present season the general stratigraphy may be well in hand, so that the details of the individual anticlinals and synclinals may be more readily obtained in the future.

The original source of the oil and gas. — There are different reasons for believing that the original source of the oil and gas was near their present position. First, the Cherokee shales and many others above them are exceedingly carbonaceous. The diamond drill core at Cherryvale reveals black, bituminous shales in great abundance at many different horizons. They frequently have an oily lustre and an odor similar to petroleum. Second, the occurrence of both oil and gas at so many different horizons, between so many different limestone systems, indicates that they were formed close to where they are now found. They could not well have come from above, and had they come from below it is probable they would have been arrested before reaching so high a geologic horizon. The great thickness of the lead-bearing limestone at the base of the Cherokee shales certainly would have caused at least portions of the oil and gas to find lodgment beneath it, which seems not to have been the case, as will presently be shown. Third, the uniform presence of salt water in the Cherokee shales and formations above them may or may not have a bearing on the question. It is an interesting fact, possibly more than a coincidence, that salt water is almost universally associated with oil and gas, so much so that it has begotten a feeling that possibly it in some way is partially responsible for their formation. Now, deep borings at Pittsburg and other points usually show that water obtained from beneath the Mississippian limestone is not saline in character, while scarcely a well is known of more than 100 feet in depth lying wholly within the Coal-Measures which is not strongly impregnated with salt.

Little inducement to penetrate the Mississippian ore-bearing formation. — Little encouragement can be found for penetrating the Mississippian formation in search of oil or gas, although they pass westward under the Coal-Measures. The more prominent reasons for this belief may be summarized as follows. First, the extensive mining operations in southwest Missouri and southeast Kansas have failed to develop even traces of oil or gas, excepting small quantities of an almost solid bitumen which occasionally is found in little pockets and crevices in the ore-bearing rocks. Had the Kansas hydrocarbons been generated below this horizon and driven through it to their present resting place, it seems exceedingly probable that greater indications of it would be met with in the mining operations. Second, at different places, notably Pittsburg and Girard, wells have been drilled several hundred feet below the base of the Cherokee

shales, searching for artesian water. At Pittsburg five such wells have been drilled, the deepest of which went over 1,000 feet below the Cherokee shales. Neither salt water, oil, nor gas was found in any of them, the water obtained being used as a supply for the city. Pittsburg is situated near the top of an underground ridge in the surface of the lead-bearing rocks, which probably is an anticlinal ridge. Should gas ever have passed from below upwards through this heavy limestone, some of it would certainly have lodged beneath this anticlinal, and the Pittsburg wells would have discovered it. The Girard well was similar, but taken to a less depth. It started in the soil covering the Oswego limestone, and went 357 feet below the base of the Cherokee shales. It found considerable gas within the Cherokee shales, but none below them.

This is a question of great practical importance. It is evident that if the oil and gas were generated within the Coal-Measures, the leakage where they are thin has been so great that nothing more than mere traces could be expected within them. Should they have come from below, however, there may be accumulations of them below the Mississippian limestone which could be obtained by deep drilling. For the reasons above given, such prospecting should be discouraged.

MINERAL ALTERATIONS IN THE GRANITIC ROCKS OF THE NORTHWESTERN STATES. By Prof. C. W. HALL, Minneapolis, Minn.

[ABSTRACT.]

AFTER mentioning several localities where the granitic rocks occur, and from which material has been studied, the paper discusses the structural and textural characters of the rocks. In structure there is every phase between the typically foliated, or gneisses and those rocks utterly devoid of foliation, the typical granites. Attention here is called to the principal systems of joints apparent in many areas. In Minnesota areas these joints have two general directions, N. E. and S. W., and N. W. and S. E., practically the same directions as are shown by the great mountain systems of the continent.

In texture there is great diversity from the extremely coarse granites of Waupaca and Pike, Wis., and the Black Hills uplift to such finely textured masses as are seen in Morrison County, Minn., although most masses are of about average coarseness of grain. The chemical composition of these granitic rocks is found to vary in no essential particular from that of other districts. The petrological characters are next discussed, and several stages of alteration were named. Muscovite granites are practically absent; biotite granites are abundant, and they merge into hornblende granites through a series of intermediate hornblende-biotite stages; the hornblende granites shade into those with pyroxene in the central parts of segregated basic mineral constituents. The feldspars do not show the same marked stages of alteration as do the bisilicate minerals.

We must, therefore, in the granites in this group of States, as has been pointed out for other localities, look for a pyroxene-bearing rock as the original type out of which, through varying alterations — stages, — these rocks have sprung.

THE ZINC MINES AT FRANKLIN FURNACE AND OGDENSBURGH, N. J. By Prof. J. F. KEMP, School of Mines, Columbia College, New York.

[ABSTRACT.]

THE paper briefly sketched the history of the mines, their general situation, and the geology of the country. It next described the Ogdensburgh ore-body, as regards shape, character, and mineralogy. The Franklin Furnace ore-body was then treated in the same way. The probable method of origin was discussed. Finally, a list of minerals was given, and suggestions were made to those intending to make the proposed excursion. (The paper was illustrated by specimens and lantern slides, and was preliminary to an excursion to the locality. It will be found, nearly as read, in the Transactions of the N. Y. Academy of Sciences, XIII. 76.)

THE GEOLOGICAL SURVEY OF THE GREAT LAKES. By J. W. SPENCER, Ph.D., F. G. S. A.

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Problems and Progress. — "Problems settled in the rough and ready way by rude men, absorbed in action, demand renewed attention and show themselves to be still unread riddles — when men have time to think, . . . doubt . . . refuses to be cast out." In such a condition was our knowledge of the history of the lakes when the writer commenced his fragmentary studies nearly fifteen years ago. In these studies of the lakes, some of the most interesting and important questions in dynamical, agricultural, and artistic geology are involved. Even if the Great Lakes had attracted the attention due to them, their study would have been impracticable at an early date, at least until after extensive soundings had revealed their characters, and numerous railway levels had furnished data for quantitative measurements. Many deep well borings were needed to discover the buried topography, and the surveys of the deserted shores have delimited the boundaries of the shrinking lakes, and the deformation of the earth's crust.

From intimate familiarity with the topographic features of the south, and comparing them with those of the lake region, one can easily see that there is very little difference between the features of the north, where the superficial drift is removed, and those of the south where no such mantle occurs. Accordingly the meteoric origin of the great St. Lawrence basin suggests itself, but it has been obstructed, and several great lakes now occupy what were once broad rolling plains. Before men had time to study out the lake history, we

were told that the lakes were valleys of erosion, but how they were made was hardly a question worthy of consideration. Later, it was an equally rough and ready method to tell us that the basins were excavated by glaciers. Their whole history is not yet written, but many chapters are now known. Extracts of these will be given in their natural order (not in that of the discoveries), so that a short story of the lakes can be told.

Former High Continental Elevation. — As will be seen in the next paragraph, the basins of the lakes are more or less like erosion valleys. The deepest sounding of Lake Ontario is 491 feet below sea level; of Lake Huron, 168 feet; of Lake Michigan, 282 feet, and Lake Superior over 400 feet. Consequently if these were erosion valleys, they must have been formed at such an altitude that the drainage of the region could have descended to the sea. As collateral evidence of the high elevation, we find that the lower St. Lawrence River is only a deep submerged valley, with tributary *cañons*, having a general depth increasing from 1,200 to 1,800 feet, but much deeper at the end. Hudson's Straits, the Gulf of Maine, New York Harbor, off the Delaware, and other points of the continental margin, reveal great submerged *cañons* that were once river valleys.[1] Indeed portions of the continent were once very much higher than now, especially in the south, where the coast and the Antillean region appears to have sunk probably two and a half miles in the later geological times. These changes of levels have been in undulations, with the greatest subsidence along the coastal regions, and more particularly in the south than in the north. But this forms a separate and partly written chapter in which much progress has been recently made. It is sufficient to know that the lake region appears to have stood at a high elevation during most of the time from the Carboniferous to the Pleistocene days which were closed by a continental subsidence much below the present altitude of the land.

Character of the Lake Basins. — The valley-like character of the lake basins appears to be challenged when the casual observer finds that the outlets are entirely or mostly closed by rocky barriers. This condition gave rise to the hypothesis of the glacial origin of the basins, for the theorists did not stop to compare the course of the basins and the escarpments with the direction of the striæ. However much one might doubt the correctness of the hypothesis, the direct futility could only be confirmed when the causes of the barriers were discovered, which will be seen below to have been the drift filling of the old valleys and the warping of the earth's crest. But the basins are river-like and broad submerged valleys. Ontario is 247 feet above the sea, but its greatest depth is 738 feet, and throughout a considerable portion of it the southern side is bounded by high vertical but submerged rocky walls which for long ages formed bluffs along the ancient river.[2] Besides the longitudinal trough another deep channel crosses the basin east of Toronto. Lake Erie is 573 feet above tide, but it is generally less than 100 feet deep except in one small area, where

[1] "The High Continental Elevation preceding the Pleistocene Period," Bull. Geol. Soc. Am., Vol. I., 1889, p. 65. "Post Pleistocene Subsidence, *versus* Glacial Dams," Bull. Geol. Soc. Am., II., 1890, p. 465. "Terrestrial Submergence Southeast of the American Continent." Bull Geol. Soc. Am., Vol. V., 1893, p. 19. All by J. W. Spencer.

[2] "Notes on the Origin and History of the Great Lakes, by J. W. Spencer." Proc. Am. As. Ad. Sc., Vol. xxxvii., 1888, p. 197. "Origin of the Basins of the Great Lakes of America," by J. W. Spencer. Quar. Jour. Geol. Soc., London, Vol. xlvi., 1890, p. 523, and earlier papers.

it is 210 feet; but through the shallow basin there are many buried channels the deepest of which at Cleveland (Newberry) is 228 feet. Michigan, Huron, and Georgian Bay are at one altitude of 582 feet above the sea. Georgian Bay is in most places only little more than 100 or 200 feet deep, but upon the southwestern side a channel reaches a depth of 510 feet along the foot of a very high escarpment, part of which is submerged. Another submerged escarpment crosses Lake Huron. This is over 400 feet high. The deepest sounding is 750 feet. The two basins of Lake Michigan (respectively 864 and 576 feet deep) have vertical escarpments adjacent to them. Also there are some deep channels and fjords, one of which is 612 feet deep. Lake Superior has been less studied. More or less drift is known to occur between the lake basins like that filling the submerged valleys under Lake Erie. The buried valleys will explain the connection between the lakes.

Glaciation of the Region. — Briefly generalized, the striation of the rock surfaces are nowhere parallel to the direction of the escarpments, whether these be submerged or above the level of the lakes, where they form bold topographic features. Nor are the vertical walls of the limestone escarpments glaciated by lateral polishing. In short the striæ are at considerable angles, even at right angles, to the rocky escarpments. Thus it appears that the valleys were not shaped by glacial action.

Buried Laurentian Valley. — Below the outlet of Lake Ontario, the valley is covered to some extent with drift, but the greater part of the barrier closing the lake is rocky. Between Georgian Bay and Lake Ontario, the writer discovered a deeply buried valley (by a series of borings, for there is no superficial evidence of it, although parallel to the Niagara escarpment) beneath the great drift ridges intervening between the two waters. The full depth has not been reached, although not less than 700 feet beneath the higher ridges, and very much more, judging from the fjords at both ends (in Lake Ontario and Georgian Bay), so that here we have the connecting valley between the submerged channels of the upper lakes and Ontario. The fjords of northern Michigan and the buried channels continue the evidence that from Lake Michigan to the outlet of Ontario, the ancient Laurentian River flowed as shown upon the map. It is thus named to distinguish it from the modern St. Lawrence River. The continuation of the valley of Superior to the Laurentian River has not been determined, but judging from soundings in Lake Michigan, it may have been by way of the northern end of that lake.

Buried Tributaries. — A southern branch of the Laurentian River, now buried beneath 500 feet of drift, extended from the southern basin of Lake Michigan, crossing the Michigan Peninsula and the southern end of the Huron Basin. This large tributary has been named the Huronian River, and is of the same age as the Laurentian River.

Through the Erie Basin flowed the now buried and submerged river, named the Erigan. Niagara River was not then in existence. But the Erigan passed from the Erie Basin across the Province of Ontario to the great *cañon* at the head of Lake Ontario and descended to the lower level.[1]

Many branches and smaller tributaries are known to have joined these

[1] "Origin of the Basins of the Great Lakes," cited before. Also, "Discovery of the Preglacial Outlet of the Basin of Lake Erie into Lake Ontario." By J. W. Spencer, Proc. Am. Phil. Sc., Phila. 1881.

greater rivers from discoveries made by borings. In some cases there were no changes in the directions of the ancient and the modern drainage. In other cases, the modern streams have locally left stretches of the original water-ways, but again returned to the old valleys. A characteristic of the old drainage is the filling of the ancient channels, above which the modern streams flow over accumulations of drift. The ancient valleys are relatively much broader, with sides more sloping (and other marks of antiquity) than the modern streams where they have made new channels in place of reopening the buried valleys.

Reversal of the Drainage of the upper Ohio and other Rivers. — Among the earlier studies of buried valleys were those of Dr. J. S. Newberry, Dr. T. Sterry Hunt, and Mr. J. F. Carll. To Mr. Carll belongs the credit of first working out the reversal of the drainage in western Pennsylvania, when he discovered that the upper Alleghany and some other streams flowed into the Erie Basin before the Pleistocene period. In 1881 the writer, following Carll, pointed out that there was evidence that the whole upper Ohio River above Pittsburg flowed to the Erie Basin. This was advanced by Dr. P. Max Foshay, and lately the observations have been extended by Prof. T. C. Chamberlin and Mr. Leverett, confirming this change of drainage. So also the streams south of Lake Erie generally drain a much smaller basin than formerly. All this is in harmony with a formerly relatively higher southern elevation compared with the northern than at present. So, in New York, the upper waters of the Susquehanna and tributaries drained through the finger lakes into the Ontario Basin — these sheets of water having been the old river courses closed up by deposits of drift and terrestrial warping or deformation towards the north.

Closing of the Valleys into Lake Basins. — The old Laurentian valley was more than one hundred miles wide, but it was interrupted by the deposition of drift in many places, — most notably between Georgian Bay and Lake Ontario. To some extent the modern St. Lawrence River is over a drift filled channel. This obstruction has caused the modern drainage to be changed from the old directions and often to pass over rocky barriers. But in addition to this obstruction, we find that the recent terrestrial uplift has been greatest towards the northeast, producing barriers forming basins. This warping has been measured and found sufficient to account for all the rocky barriers below the outlet of Lake Ontario. Moreover, this northeastern elevation has caused all the lakes to rise and flood their southern or western ends since the modern lakes were established. The quantitative character of this change will be explained in the next paragraph, and the effects upon the modern drainage below.

Deserted Beaches in the Lake Region, and their Deformation. — The lake region abounds with remains of deserted beaches, terraces, sea-cliffs and other evidences of former shore lines. The writer has made extensive surveys of these phenomena on the Canadian side of the lakes, across Michigan, in the Adirondack region and elsewhere. Mr. G. K. Gilbert did the first systematic work south of Lakes Ontario and Erie. Mr. F. B. Taylor has recently extended the surveys north of Lake Michigan and Huron, and Dr. A. C. Lawson, north of Lake Superior. There has been very little systematic work in the lake region upon these problems except by the named observers.[1] Some of these old shores

[1] "Notes on the Origin and History of the Lakes," 1888, cited before. "Deformation of the Iroquois Beach and Birth of Lake Ontario," Am. Jour. Sc., Vol. xl., 1890, p. 443; "Deformation

after forming highways, known as "ridge roads," have been surveyed for hundreds of miles. Others are broken and interrupted. Generally speaking, their northeastern extensions are unknown owing to want of surveys, to the changes in topography rendering their survey difficult, owing to our ignorance of all the phenomena, especially of suspected modern faults, and to further ignorance as to how much of the old shore structures are obliterated by denudation and by ice action. This last question involves the problems of the subsidence of the region and of the character of ice dams. Mr. Gilbert thinks that our want of knowledge of the northeastern extension of the waters held in by the deserted shores is due to their delimitation in that direction by glacial dams at high elevations. The writer thinks that the beaches were substantially formed at sea level whether their outlets were obstructed by floeberg or local ice accumulations, or the northeastern continuity obliterated by recent faults or other phenomena not yet described but not by glacier dams. Though much is still to be done in the survey of the infant lakes, yet we have some interesting contributions to the lake history, even without disturbing our repose concerning the still unread history. Fragments of beaches occur in the peninsula between Lakes Ontario, Erie, and Huron up to altitudes of nearly 1700 feet, and terraces in the Genessee valley at a much greater height. Also at high levels elsewhere in the lake region. But when we descend to an altitude of 778 feet at the head of Lake Erie, there is a beach of great extent, and one more extensive in descending to 653 feet. All of the higher developments are the remains of the first waters that covered the drift at the close of the Pleistocene period, whether they were ice-bound arms of the sea or glacial dams. The beaches are not now water-levels, but rise towards the north and east in increasing ratio. At the head of Lake Erie, they are nearly level, at the eastern end of the lake the northern rise is between three and two feet per mile, according as we take the uplift on the higher or lower beaches. East of Georgian Bay the deformation is four feet, and near the outlet of Lake Ontario from five to six feet per mile towards the northeast but increasing, and this is recorded in the remains of shores not the highest. And there were many other lower stages of the lakes.

Warren Water and Birth of the Lakes. — The open water represented by the succession of contracting beaches the writer has named Warren Water, the mother of all the lakes, and its lowest strand is the Forest Beach, which has an elevation of 653 feet at the head of the Erie Basin. This lake during part of its history covered 200,000 square miles. But to the east it has not been defined, and its old margins have been tilted up very considerably. With the continued rise of the land, the waters sunk to a lower level, dismembering Warren Water, and producing:

of the Algonquin Beach and Birth of Lake Huron," The same, Vol. xli., 1891, p. 12; "High Level Shores in the Region of the Great Lakes and their Deformation," The same, p. 201; "Deformation of the Lundy Beach and Birth of Lake Erie," the same, Vol. xlvii., 1894, p. 207; "The Iroquois Shore North of the Adirondack Mountains," Bull. Geol. Soc. Am., Vol. iii., 1891, p. 488. All by J. W. Spencer. "The History of Niagara River," by G. K. Gilbert, Sixth Rep. Com. State Res., N. Y., 1890, and some earlier scattered abstracts. "Sketch of the Coastal Topography of the North Side of Lake Superior, with Special Reference to the Abandoned Strands of Lake Warren," by A. C. Lawson; "20th Report Geological Survey of Minnesota," p. 181; "A Reconnaissance of the Abandoned Shore Lines of Green Bay," by F. B. Taylor, Am. Geol. Vol. xiii., p. 316.

Algonquin and Lundy Waters. — When the level of the waters fell about 150 feet below Forest Beach, the three highest lakes were enclosed within Algonquin Beach, and Erie within the Lundy Beach, which extended to the Ontario Basin. At that time the waters of the lakes did not reach to their western and southern boundaries of to-day. Towards the northeast they connected by straits with the waters in the Ontario Basin, but their eastern limit has not been surveyed.

Iroquois Water and Birth of the Modern Lakes. — Then gradually subsided the waters to a level 300 feet below the plains of the Algonquin and Lundy Beaches, when the Iroquois shore commenced to be formed. This level was undoubtedly at that of the sea, although it is now 363 feet at the head of Lake Ontario, 780 feet near the outlet of that lake, and nearly 1500 feet farther east. This old water plain is recognizable by interrupted portions of the old shore all the way to the depression of Lake Champlain, but it is not yet fully known, nor its location north of the Ottawa River. Lower beaches are also known in the Ontario Basin.

With the subsidence of the waters to the Iroquois level, the upper lakes shrunk within very narrow limits, and Niagara River had its birth and drained only the Erie Basin, whilst the three upper lakes drained by way of the Ottawa River valley. Indeed, the Iroquois waters sunk over 200 feet below the Iroquois Beach, producing the lakes contracted about their heads, but expanded far towards the northeast. By the continued rise of the land towards the northeast, the rims of the lakes were raised, backing the waters in the basins, and extending the modern lakes as we see them. This rise was intermittent, but for the average of the secular episodes of movement and repose, the warping in the Niagara region appears to have been only one foot and a quarter a century, but double that amount at the outlet of the Lake Ontario.

The Drainage of the Great Lakes into the Mississippi River by Way of Chicago. — Frequent reference has been made to the outlet of the Michigan Basin by way of Chicago and the Mississippi valley. Having surveyed many portions of the deserted strands of the lake basins, I now take the liberty of presenting the history of the Chicago outlet in the light of the discoveries.

Long ago, Dr. E. Andrews described the deserted beaches south of Chicago, and found that the highest reached an elevation of 45 feet above the lake. For many miles, round the head of the lake, the deserted shores are found far inland. There are other raised beaches nearer the lake. The different sets form an apparent succession, but in reality there is some confusion between the old water-margins and the very recent beaches. The low plain at the head of the lake rises so gradually that the divide between it and the Mississippi drainage is hardly noticeable to the eye a few miles southwest of Chicago. The divide is only eight feet above the lake, with a rocky floor a foot or two lower. (Canal survey.) In the survey, the late drainage channel is noticeable, and it is about a mile wide. In proceeding northward along the margins of the Michigan Basin, beaches are found emerging from beneath the waters. From the measured deformation of the various sets of deserted shores, the depth to which the tilted beaches are depressed beneath the lake can be calculated.[1] These

[1] "High Level Shores in the Region of the Great Lakes and their Deformation," by J. W. Spencer, Am. Jour. Sc. vol. xli., 1891, p. 201.

record the shrinking of the lake from the highest level south of Chicago to others even hundreds of feet beneath.

The Ridgeway Beach extends from the Erie Basin across southern Michigan, by way of Saginaw Bay and the Grand River valley, and southeast of Lake Michigan it descends and is lost in the sand dunes of that region; but with the measured rate of deformation, it is computed to pass about 40 feet beneath the surface of the water near Chicago. The Forest Beach, the last strand of Warren Water, is about 100 feet lower. The still lower Algonquin Beach (the great shore-line of the dismembered upper lakes[1]) occurs well defined about the northern half of the lake (Taylor), but if produced to the southern end of the basin, it would be submerged between 250 and 300 feet. There are other lower and less important deserted shores; but all of these represent the subsiding of the lake as the waters of Lake Huron were being discharged by way of the Ottawa River, which drained that basin for about 24,000 years.[2]

The highest of the beaches about the head of Lake Michigan (at 45 feet) has been regarded by this survey as the equivalent of the Maumee Beach, or not a lower strand, and therefore the oldest well-defined beach of the region, although only a few feet above the present and recently deserted shores.

Owing to the terrestrial deformation, the Ottawa outlet of the Huron Basin was closed by the rim being raised so high as to turn the overflow into the Erie Basin. This northeastward uplift also affected the outlet of the Erie Basin, and on account of the presence of Johnson's ridge, about a mile north of the present site of the Falls of Niagara, caused an actual overflow of the drainage of all the upper lakes into the tributaries of the Mississippi River. At that time the lacustrine silts upon the prairies at the head of the lake were laid down. But the Niagara Falls were receding at the rate of about four feet a year and effected the incision through the Johnson ridge about 1500 years ago,[3] thus overcoming the terrestrial uplift of the Niagara district (which is about a foot and a quarter a century) and then the level of Lake Erie was lowered about 17 feet below the Chicago divide. The slightly raised beaches about the head of Lake Michigan marked this subsiding of the waters. The lowering of the waters by the recession of the falls has preserved the present outlet of the lakes for a further period, but if the late rate of terrestrial deformation shall continue in the future, as during the time when the drainage of the Huron waters were being turned from the Ottawa valley to the Niagara, then the drainage of the upper lakes will be diverted from the Niagara into the Mississippi in perhaps 5,000 or 6,000 years hence, that is before the falls shall have receded to Buffalo.

History of the Niagara River. — This subject forms a chapter in the Lake History, of which an abstract under another title follows.

[This paper is reprinted in American Geologist, Vol. XIV., Nov. 1894.]

[1] "Deformation of the Algonquin Beach and Birth of Lake Huron," by J. W. Spencer. Am. Jour. Sc. vol. xli., 1891, p 12. Also the Notes of F. B. Taylor, since published.

[2] "Duration of Niagara Falls," Am. Jour. Sc., vol. xlviii., p. 455, 1894.

[3] "Deformation of the Lundy Beach and Birth of Lake Erie," by J. W. Spencer. Am. Jour. Sc. vol. xlvii., 1894, p. 297.

Duration of Niagara Falls. By J. W. Spencer, Ph. D., F. G. S. A.

[abstract.[1]]

Prior to the writing of the present paper, most of the conjectures as to the age of the falls were based upon the supposed uniform rate of recession alone. In 1790, Andrew Ellicott assigned 55,000 years as the age of the falls; in 1841, Sir Charles Lyell allowed 35,000 years; in 1886, Prof. R. S. Woodward, after three surveys had been made, calculated the age at 12,000 years; and later, Mr. G. K. Gilbert, under uniform conditions with recession at the maximum axial rate of retreat, showed that the duration of the falls would be reduced to 7,000 years. This was not intended for an estimate, as he recognized that such a computation must have been greatly increased by many changing conditions. The rate adopted by the first two writers was only conjectural, as no surveys had been made. Three surveys of the falls had been completed before the calculations of the latter two named writers, and I have had the benefit of a fourth survey, — that of Mr. Aug. S. Kibbe, in 1890. Woodward's calculation was upon the mean mathematical enlargement of the horseshoe gulf at the end of the chasm, which rate has been less than the geological rate of recession. The author's methods differ from the others in that it takes into consideration the rate of recession throughout the changing episodes of the river, which have been entirely discovered by Mr. Gilbert and himself.

The detailed topography has formed a necessary study in order to arrive at the character of the work done during the various episodes of the river. So also the geological sections had to be resurveyed, as general impressions were not sufficient.

The Niagara River is modern, still the ancient topography has some bearing upon the retreat of the falls, although but little. The modern river crosses an ancient broad valley, nearly a hundred feet deep, in the vicinity of the falls. This depression has escaped the attention of geologists, especially in its bearing upon the history of the falls. The peculiar extension of the chasm at the whirlpool and the buried valley of St. David's have been considered by many as part of a pre-glacial Niagara River. This is now found to be a shallow branch of a buried valley outside of the Niagara *Cañon*, and hundreds of feet shallower, with ancient sloping V-shaped walls, whilst those of the gorge are vertical. It is only an incident that the modern river touches this drift-filled valley, but it has given rise to the elongation of the chasm at the whirlpool. The drainage of the table-land of the Niagara Peninsula was across the direction of the Niagara River, and was strongly marked by bold limestone ridges, which have only been penetrated by the falls in modern times. Even drainage of the ancient Erie Basin emptied by a route forty miles west of the Niagara River.

Portions of the banks of the Niagara River, before the waters sunk into the chasm, flowed over hard limestones, and other portions crossed drift-filled depressions in the ancient topography, but the banks of the river before the excavation of the gorge are well defined.

The modern recession of the falls is computed from four surveys extending

[1] Printed in full in Am. Jour. Sc., vol. xlviii., p. 455, 1894.

over 48 years. The mean rate of recession is found to be 4.175 feet a year. This rate has been variable with secular episodes of rapid medial retreat, followed by the cessation of work along the axis, but with increased lateral recession. The cycle appears to be about fifty years in duration. This rate of over four feet a year, however is excessive, if the whole history of the falls be considered, on account of the geological conditions favoring the rapid modern retreat; accordingly, this coefficient which overrates the mean recession of the river compared with the present discharge, is reduced to 3.75 feet a year.

The history of the adjacent lakes had to be discovered before that of the Niagara River could be told. At one time the greater proportion of the lake region was covered with one sheet — or Warren Water. Upon its dismemberment in part, at least, by the rise of the land, one large lake (Algonquin) was formed, occupying the basins of Huron, Michigan, and Superior; and another (Lundy), a portion of the Erie Basin extending into the Ontario Basin. The waters in these two basins were subsequently lowered so that they fell to their rocky eastern rims, and the three upper lakes discharged by way of Lake Nipissing and the Ottawa River, and the Niagara had its birth, — draining the Erie Basin alone. Then the Niagara River cascaded only 200 feet. In course of time the waters of the lower lake subsided 220 feet more, but eventually they were raised again 80 feet at the mouth of the Niagara, — thus reducing the descent of the river, from the head of the rapids above the falls to the foot of the last rapids in its course to the lake, to 320 feet. During the lowest stage, Lake Ontario receded twelve miles from the end of the Niagara gorge, where the falls had been located at its nativity.

Theoretically, the rate of erosion varies as the height of the falls and the volume of the water, but some of the work is converted into heat. The recession of the falls is largely due to the work being expended in the undermining of the hard capping rocks, by the removal of the underlying shales. The rate of the modern recession has been determined under changing conditions of erosion, so that the theoretical variations of other portions of the work include their modifications.

The different conditions which obtained during the various episodes modified the rate of erosion, so that each has to be treated separately. First episode: — water falling 200 feet, its volume $\frac{3}{11}$ of the modern discharge, gorge 11,000 feet long (to the terrace of Foster's flats); duration 17,200 years. Second episode: — river descending 420 feet in three cascades, — first stage, only the discharge of the Erie waters, length of chasm 3,000 feet (in front of Foster's terrace and deepening older part of *cañon*); duration 6,000 years, — second stage, drainage of all the upper lakes, length of chasm 7,000 feet (to the Narrows above the Whirlpool); duration 4,000 years. Third episode: — volume as before, and also the descent, but in one cascade; length of the contracted chasm, occupied by the Whirlpool rapids 4,000 feet; duration 800 years. Fourth episode: — volume of water as at present, with the level of the lower lake as to-day; first stage, a local rapid as at Johnson's ridge, with the total fall of the water 365 feet, work particularly hard, length of gorge 5,500 feet; duration about 1,500 years; second stage as at present, work easy, length of *cañon* 6,000 feet, descent of water 320 feet, rate of recession taken is that of the full measured amount of 3.175 feet a year; duration about 1,500 years. Thus the age of the falls is computed to be 31,000

years with another 1,000 years added as the life of the river before the nativity of the falls. The turning of the Huron waters into the Niagara was about 8,000 years ago. The last difficult question to determine was the amount of work done in each episode. This was eventually found by the position of the terraces corresponding to the different stages of the river, and the changing effects of erosion.

The effects of the terrestrial movements upon the falls were to change the height of the cascade during different episodes, and eventually to greatly increase the discharge of the Niagara River. The deserted beaches in the lake region have been deformed by unequal terrestrial elevation, but preserve the record of this movement. The local deformation affecting the Niagara Falls since the commencement of the river epoch amounts to 2.5 feet rise per mile towards the northeast; 4 feet northeast of Lake Huron; and 5 feet at the outlet of Lake Ontario. Taking the amount of elevation in each district as also representing the proportional measure of time, then the calculation can be made upon several of the beaches, and in terms of the age of Niagara, their antiquity can be inferred. The importance of their computation in this paper is that they support the correctness of the calculations as to the age of the falls. In the application of these results it appears that the rate of terrestrial uplift in the Niagara district is about 1.25 feet a century, 2 feet east of Lake Huron, and 2.5 feet at the outlet of Lake Ontario. In this study was found for the first time the long looked for indication of the rate of uplift.

As to the relation of Niagara Falls to geological time we would have to take another step outside the present study before it is entirely settled. It appears that from the commencement of the lake epoch to the birth of the falls, according to the beach records, from half to as long a time elapsed as the age of Niagara River; thus it would seem that the lake epoch commenced at from about 48,000 to 64,000 years ago. Against this conjecture there is no evidence. But then follows the question, what relation existed between the end of the Ice Age and the birth of the lakes? If the Ice Age ended with the birth of the lakes, then we have a time-piece by which the date can be read. On the other hand, if the lakes were held in by glacial dams, then the Ice Age has been considered by some to have continued to about the close of the Iroquois epoch, or 14,000 years ago as determined in this investigation. The phenomena recently observed in New England negative this assumption. Accordingly, the end of the Ice Age was not less than from 48,000 to 60,000 years ago.

The end of the falls seem destined, if we read the future by the past, to be effected, not by the erosion expending itself on the rocks, but by terrestrial deformation turning the drainage of all the upper lakes into the Mississippi, by way of Chicago, just as the Huron waters were lately turned from the Ottawa into the Niagara drainage; and at the recent rate, it would seem that about 5,000 or 6,000 years at most will be needed. The change of drainage should arrive before the cataract shall have receded to Buffalo.

THE CARBONIFEROUS STRATA OF SHASTA COUNTY, CALIFORNIA. By Prof. JAMES PERRIN SMITH, Stanford University, California.

[ABSTRACT.]

THE general structure of the metamorphic region is briefly described. The Paleozoic section is outlined, and the faunas of the Carboniferous discussed. Especial attention is given to a Waverly fauna, above the stratigraphic position of the Waverly. The author seeks to prove that when the fauna had died out in the Mississippi valley region, it lived on in the West. A migration of these forms, due to shifting of physical barriers, is thought to explain supposed *colonies* in Arkansas and Missouri.

The entire Carboniferous of Shasta County is subdivided into local divisions, on the basis of its lithological and its faunal characteristics.

THE GEOLOGICAL ATLAS FOLIOS ISSUED BY U. S. GEOLOGICAL SURVEY. By F. H. NEWELL, U. S. Geological Survey, Washington, D. C.

ON STANDARD SIZES FOR TRAYS, DRAWERS, AND CASES FOR MINERALOGICAL AND MICROSCOPICAL CABINETS. By W. G. LEVISON and Prof. D. S. MARTIN, Brooklyn, N. Y.

THE LATER GEOLOGICAL CHANGES IN CUBA. By Dr. J. W. SPENCER, Atlanta, Ga.

THE AGE OF THE GALENA LIMESTONE. By Prof. N. H. WINCHELL, Minneapolis, Minn.

THE COLUMBIAN FORMATION IN NORTHWESTERN ILLINOIS. By OSCAR H. HERSHEY, Freeport, Ill.

[Paper will be printed in the American Geologist, Jan., 1895.]

EXHIBITION OF MAP AND PHOTOGRAPH OF A PEAT BED IN PROSPECT PARK, BROOKLYN, N. Y., MADE IN 1867, WHEN THE PEAT WAS REMOVED AND THE EXCAVATION FILLED. By WALLACE GOOLD LEVISON, Brooklyn, N. Y.

EXHIBITION OF A MICROSCOPE MADE OF ALUMINUM FOR PORTABILITY, AND MODIFIED IN CONSTRUCTION TO ADAPT IT FOR SEARCHING OVER THE SURFACE OF LARGE MINERAL SPECIMENS. By WALLACE GOOLD LEVISON, Brooklyn, N. Y.

A PREHISTORIC RELIC, WITH EXTRACTS FROM A SURVEY OF LANDS IN MONROE AND ONTARIO COUNTIES, N. Y. By C. H. JENNER, Brockport, N. Y.

THE MINERALS OF PATERSON, UPPER MONTCLAIR, AND THE PALISADES, N. J. EXHIBITED BY THE LOCAL COMMITTEE. By JOS. H. HUNT, Brooklyn, N. Y.

ON THE AGE OF THE ST. CLAIR LIMESTONE OF ARKANSAS. By S. H. WILLIAMS, M. D., Randall's Island, N. Y.

SECTION F.

ZOÖLOGY.

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PAPERS READ.

NOTES ON THE GENUS PERIGONIMUS, SARS. By Prof. CHARLES W. HARGITT, Syracuse, N. Y.

THE genus *Perigonimus* includes a group of rather small Hydroids, of rather interesting habit and structure.

It was instituted in 1840 by M. Sars [1] upon characters possessed by specimens found on the coast of Norway, and described by him in the "Fauna Littoralis Norvegiæ," in 1846.

Sars's description is brief, and either seriously at fault, or made from a not very typical specimen, as compared with members of genus as now known.

The genus is interesting as including hydroids of remarkably primitive characters. They are mostly minute, lowly forms of the tubularians, having a single circle of tentacles, and exceedingly rudimentary skeleton, or perisarc. This covering in several of the species is a simple, slime-like secretion which covers the entire hydrocaulus, and extends in at least one case [2] to the hydranth itself, including even portions of the tentacles. If this semi-fluid, or gelatinous secretion should thicken and partially solidify, the formation of the dense, chitinous perisarc of the calyculate hydroids would find a simple explanation. That such has been the phylogenetic history of the case seems very highly probable, and finds confirmation in the ontogeny of the perisarc, which at its beginning is just such an ectodermic secretion, hardening on exposure to the water.

In habit, the species of the genus, without exception, are commensal. Many are found on the shells or opercula of marine gasteropods, or upon shells tenanted by hermit crabs. Others are found upon the skeletons of crabs, or upon other hydroids. This again is a mark of a lowly or degenerate form.

That there is some advantage conserved by the habit is certainly evident, though not always easily perceived. In Hydractinia it approaches the condition of parasitism, as I have often found specimens gorged with eggs taken from the host.

The genus is a comparatively large one, including at the present time some ten species, some of which have however been considered as of doubtful affinities.

[1] Fauna Littoralis Novegiæ, p. 8. Erstes Heft.

[2] Weismann, Die Entstehung Der Sexualzellen den Hydromedusen, p. 115.

Hincks[1] included and described five distinct species up to the publication of his "British Hydroid Zoöphytes" in 1868, and several considered by him as of doubtful relation. Some of these have since been recognized as genuine species.

Allman,[2] in the classic monograph "Gymnoblastic Hydroids," published in 1871, records and describes eight species, with two of doubtful affinities.

Weismann,[3] in 1883, described a new species found in the Gulf of Naples, taken from the spines of a sea-urchin, and named correspondingly *P. Cidaritis*. There is a slight discrepancy in Weismann's description, where he gives its size as about "9 *cent.*" He evidently intended to say 9 mm. The spines of the sea-urchin are not 9 cent. long, and it would hardly be probable that the hydroid should exceed in length the support.

In 1892, the author, with Prof. H. L. Osborn,[4] found and described the first species recorded from American waters. There seems to be no doubt that it is a new species, which we have designated P. Jonesii.

If the species thus far recorded stand, this last accession will make the number at present known as ten, not including some of which there still seems to be doubt.

In distribution the genus is rather limited. Only in one or two cases have I found records of its having been taken except along coast lines, and in comparatively shallow water.

ZOÖLOGICAL STATION, Naples, June 25, 1894.

SOME INTERESTING CONDITIONS IN WOOD RESULTING FROM THE ATTACKS OF INSECTS AND WOODPECKERS. By Dr. A. D. HOPKINS, West Va. Agric. Exp. Station, Morgantown, W. Va.

[ABSTRACT.]

IT is found that certain characteristic and common defects in wood are the result of injuries by insects and woodpeckers to the living sapwood. The defects consists of slight wounds and stained streaks extending for some distance above and below the injury. It is also found that so-called curly and bird's-eye wood are often brought about by injuries to bark and wood of living trees by woodpeckers. All the facts are based upon personal observations. Some interesting specimens of the work of woodpeckers and insects exhibited.

[Read in joint session of F. and G.]

SEXUAL CHARACTERS IN SCOLYTIDAE. SPECIMENS AND DRAWINGS EXHIBITED. By Dr. A. D. HOPKINS, West Va. Agric. Station, Morgantown, W. Va.

[ABSTRACT.]

BY dissecting male and female examples of different genera, and a study of the male genitalia, it is found that in numerous cases females have been

[1] British Hydroid Zoöphytes, p. 89, *et seq.*
[2] Gymnoblastic Hydroids, p. 321, *et seq.*
[3] *Op. Cit.*, p. 115, *et seq.*
[4] Amer. Nat. Jan., 1894.

described as males and *vice versâ*. The male characters of *xyloterus politus*, heretofore unknown, are described, and other valuable observations referred to, which are of value in classifying and describing species of this family.

THE QUESTION OF SPIDER BITES. By L. O. HOWARD, Agric. Dept., Washington, D. C.

[ABSTRACT.]

A REVIEW of the whole question as to whether spiders may or do inflict dangerous or fatal bites upon human beings. The author concludes that the evidence is conclusive with regard to the spiders of the genus Latrodectus, but inconclusive with all others. In this country under ordinary circumstances spiders are not to be feared. The prevalent exaggerated ideas are not justified. Eight-tenths of the spider-bite stories are not true. In those which are true the circumstances are very unusual. Some peculiarly thin-skinned and sensitive portion of the body has been exposed to the bite; the patient was either constitutionally susceptible to such poisons, or was in a condition of health which rendered him susceptible. Physicians have not appreciated the importance of investigating carefully such cases as come under their notice.

A MIGRATION OF COCKROACHES. By L. O. HOWARD, Agric. Dept., Washington, D. C.

[ABSTRACT.]

DESCRIBES an extensive migration of the "Croton bug" or "German cockroach" witnessed on a very dark day in Washington. Nearly all of the migrating individuals were females bearing egg-cases. It seemed to be a case of the development of the true migratory instinct, and to explain the frequent infestation of new houses by this insect.

ON THE ABOVE-GROUND BUILDINGS OF THE SEVENTEEN-YEAR CICADA. By Prof. J. A. LINTNER, State Entomologist, Albany, N. Y.

[ABSTRACT.]

OBSERVATIONS made on the "Hudson River Brood" of the seventeen-year Cicada have shown an interesting feature connected with the emergence of the pupæ in localities in New York and New Jersey. Instead of coming out of the well-known round holes at the surface of the ground, clay structures, conical or sub-cylindrical in form, have been built on the surface, in continuance of the underground shafts, to a height of from two to four inches. They first came to my notice at New Baltimore, N. Y., where an acre or more of ground was thickly dotted — in places covered — with them. They had been built at least a month before the pupæ escaped through an opening made by them at the top. The purpose that they serve, or why their construction is so exceptional,

is unknown. The literature of the insect contains but a single notice of their occurrence, viz., in 1868, as recorded by Dr. Riley.

In May last, they were found also in great number, near Nyack, N. Y., on South Mountain, distributed over an area estimated at 60 acres. They were also discovered, in less number, at several other places in New York and in New Jersey. Specimens showing their various forms and structure have been collected from the New York localities for the New York State collection, and excellent photographs have been secured for reproduction in a forthcoming Report "On the appearance of *Cicada septendecim* in New York in 1894."

THE PULMONARY STRUCTURES OF THE OPHIDIA. By Prof. E. D. COPE, 2102 Pine St., Philadelphia, Pa.

[ABSTRACT.]

THE paper describes the degenerate character of one of the lungs in the snakes, and the relation of such structures to the general characters of the genera. It describes the diverticulum of the functional lung, and its development into a tracheal lung, with the various forms of the latter, and their relations to the general system. The variations in the character of the trachea are also considered.

[This paper will be printed in proceedings of the American Philosoph. Society.]

PHOTOGRAPHING FISHES AND OTHER AQUATIC ANIMALS UNDER WATER BY MEANS OF A VERTICAL CAMERA. By Prof. S. H. GAGE, Ithaca, N. Y.

[ABSTRACT.]

THIS paper is a description of the method of photographing animals under water, with illustrations. The purpose being to show the possibility of the production of accurate and life-like pictures of aquatic animals by the aid of photography.

The paper was illustrated by a diagram of the vertical camera, and by numerous photographs of aquatic animals.

THE TRANSFORMATION OF THE LAKE AND OF THE SEA LAMPREY. By Prof. S. H. GAGE, Ithaca, N. Y.

[ABSTRACT.]

The main features of the paper are:—1. Similarity of the larvæ and of the mode of life in the lake and the sea lamprey. 2. The dissimilarity of the habitat and of the size attained by the two forms during the adult or parasitic life.

Diagrams and photographs illustrated the paper.

RELATION OF AGE OF TYPE TO VARIABILITY. By Prof. L. H. BAILEY, Ithaca, N. Y.

[ABSTRACT.]

1. THERE is a wide difference in variability in cultivated plants. Some species vary enormously. The type of lettuce, cultivated for somewhat less than 2,000 years, was early lost, and the cultivated species was named *Lactuca Sativa*, but it is really the *L. Scariola*. The type of soja bean and the sweet potato are not known. Of tomatoes the cultivated varieties are more removed from the type than many species are from each other.

2. Variability in these species is not due to age, cultivation, nor geographical distribution.

3. Variability under cultivation is due to some elasticity of the species, and is thus phylogenetic.

4. The newer the type the more readily it varies. New types are polymorphous, old types are monomorphous. The most flexible types have not yet passed their zenith, *e. g.*, Cucurbitaceæ. The varieties of cereals are so much alike that expert knowledge is needed to distinguish them.

5. Why are new types flexible? A certain answer cannot be given; but the author believes it explicable on the principle of divergence of characters rather than by any rejuvenescence of type.

[In joint session of F. and G.]

THE STRUGGLE FOR EXISTENCE UNDER CULTIVATION. By Prof. L. H. BAILEY, Ithaca, N. Y.

[ABSTRACT.]

THE struggle for existence under cultivation can be resolved into figures. Seedsmen estimate that one-fourth the seed produced is lost because unsown. (But this is less than nature wastes among wild plants.) Three-fourths therefore engage in the struggle for existence. Perhaps only one in thirty, or one in twenty, of these come to anything. The rest are thinned out. This is a struggle between members of the same species; therefore the struggle sets us a divergence within the species. Added to this is the selective agency of the weeder. The same laws which govern evolution in feral conditions, govern evolution under cultivation.

[In joint session of F. and G.]

THE WORK OF THE INDIANA BIOLOGICAL SURVEY. By A. W. BUTLER, Brookville, Ind. (In joint session of F. and G.)

THE NUMERICAL INTENSITY OF FAUNAS. By L. P. GRATACAP, Amer. Mus. of Nat. Hist., New York City. (In joint session of F. and G.) [To be printed in the American Naturalist.]

SECTION G.

BOTANY.

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ADDRESS.

BY

LUCIEN M. UNDERWOOD,

VICE PRESIDENT, SECTION G.

THE EVOLUTION OF THE HEPATICÆ.

THERE is, perhaps, a natural tendency among specialists to magnify the importance of the particular subject or group of life-forms in which they happen to be specially interested. The horticultural botanist, dreaming of the time when the world will be reorganized through the products of his art, is prone to see nothing beyond utility and ornament in plants, and it becomes a part of his nature to see some useful character in forms of vegetation which to others are devoid of either beauty or utility. The economic mycologist, over-impressed with the magnitude of the losses sustained by the unfortunate agriculturist and fruit grower, is haunted in sleep with visions of anthracnose and mildew and in his waking hours sees little in botany but host-plants bristling with parasites and Bordeaux mixtures certain to relieve them of their incubus. The man with inherent, if not coherent proclivities for priority, with a warlike temperament and a strong tendency to cross lances, sees in botany one vast battle field of synonymy in which cohorts of pre-Linnæan binomials, hordes of decapitalization dogmas, hostile homonyms and Kuntzian curiosities charge down upon each other in battalions, form and *reform* in utter confusion. There are some microscopic botanists whose degree of specialization never permits them to look outside the limits of an apical cell; and others still whose botanical horizon is bounded by

the field of an immersion lens and whose azimuth and right ascension are calculated within its limits. We are all more or less inclined to ride our own hobbies in public places; so in performing the initial function of this office, I can perhaps do no better than to bring forth mine. In this way, I shall at least be in touch with present custom.

With no desire, however, to overestimate its importance, I wish to place before you the position in the botanical system, of a comparatively obscure group of plants and to call your attention for a brief time no less to their own differentiation than to their important relation to the evolution of the plant world. I desire to set forth in something of a reasonable way the characters of the group and to correct some misunderstandings that have resulted from an imperfect appreciation of its relations. The group commonly known as Hepaticæ has suffered at the hands of general botanists, and through them an incomplete and one-sided conception is transmitted to the generation of botanical students now coming to their maturity. The average text-book of botany emphasizes strongly the representative character of *Marchantia polymorpha*. In elementary laboratory guides, this is even made to stand as the sole representative of all the Bryophytes. In those somewhat more comprehensive, it is made a type of the more limited group of the Hepaticæ, and in even the most complete it is made to stand preeminent as the representative of this triply developed group of plants, notwithstanding the fact that the other members of this trio are vastly more important—one in the nature and extent of its development *per se* and the other in its important relations to the development of the higher groups of the plant world. One elementary text-book that has in general done much to elevate the standard of botanical teaching in America during the past decade opens its account of the Hepaticæ with these words: "In the Liverworts the plant body is for the most part either a true thallus or a thalloid structure. When there is a differentiation into stem and leaves, etc."[1] This statement may be taken as fairly representing a conception of the group common among botanists and botanical teachers. The hepatics among us are popularly supposed to be thallose or thalloid plants and *Marchantia* is regarded as a normal representative. As opposed to this wide-spread misconception, it should be noted that, as far back as the date of the last publication of a general synopsis of the Hepaticæ (1847), the relative numerical

[1] Cf. also our most recent text book by Vines p. 334.

importance of the Marchantiaceæ was only 17 per cent of the entire group and the increase since that time has been even more largely in the direction of the other groups especially the foliaceous Jungermaniaceæ which represent at once the most numerous and best differentiated types of the Hepaticæ.[1] It would be even less a misrepresentation of the Musci to make its representatives in *Andreæa*, *Phascum* or *Buxbaumia* than to place *Marchantia* or any of its allies as a normal representative of the Hepaticæ. Armed, however, with such a conception gained from the elementary texts and emphasized by the works of reference usually accessible in an ordinary laboratory, as for example Kny, Strasburger, Sachs and Goebel, the student goes forth into the field to study liverworts and after he has exhausted *Marchantia* and *Conocephalus*, and has possibly seen a *Riccia*, he is usually stranded and knows not what to seek. In fact, many are more likely to confuse some such thallose lichen, as *Peltigera*, with liverworts than to look for them among leafy forms which their training has not rendered them able to correlate properly. The *Lophocoleas*, the *Cephalozias*, the *Frullanias* and the *Radulas*, so elegant in their structure as to impress the least æsthetic student with their beauty, so diversified in their evolution as to demand the exercise of his most active powers of reflection, and withal so simple in structure as to render them accessible with a minimum of microscopic technique—these are a closed volume to him because of the limitations of his early instruction and impressions.

The group known since the time of Adanson as the Hepaticæ stands in a unique position on the boundary line of thallose and leafy plants, and its position is not only intermediate from the structural standpoint, but in its relation to the evolution of the higher plants it stands as a key or link between the lower and simpler and the higher and more complex. The group is not a compact one nor are its component groups closely united to each other. It is even to be doubted if a good reason exists for the separation of the Bryophytes into the two classes, Musci and He-

[1] The relative extent of the Jungermaniaceæ as developed by modern exploration and subsequent study can be seen in a comparison of a few representative genera:

	Species described in Synopsis Hepaticarum 1844–7.	Species reported by Schiffner 1893.
Metzgeria,	8	36
Lophocolea,	69	149
Plagiochila,	179	468

paticæ, and it would be hazardous to attempt their separation as coördinate groups on any rational grounds, even if we leave in question their relation to the Sphagnaceæ.

The hepatics possess almost absolutely no utilitarian aspect. Beyond the doubtful use of one or two in medicine, and the occasional occurrence of one or more tropical species as weeds, they are, so far as the physical condition of the human race is concerned, an entirely useless group of plants. They do not trouble the experiment station botanist, the horticulturist finds no use for them, and the general public does not see sufficient importance in them to subscribe a single shilling for the endowment of a laboratory for research in such an apparently barren field. And yet from the higher standpoint of genetic relationship, there is probably no single group of plants that occupies such a unique position in the plant world. What the comprehensive and heterogeneous group *Vermes* is to the animal kingdom, the Hepaticæ are to plants, with this difference, that we have here a much less complicated group of organisms with which to deal.

To understand more fully the relation of the Hepaticæ to the evolution of the green plants and particularly to their rôle in the development of the alternation of phases of reproduction which has attained such extended proportions in the ferns and other Pteridophytes, it is desirable to bring in brief review the successive stages in the processes of reproduction from the simplest forms upward. For it must be remembered that even if the methods of reproduction cannot serve as the means of separating the primary types of the Thallophytes in a natural system of classification, they nevertheless represent the highest function that is manifested in organic life. The successive stages may be characterized as follows:—

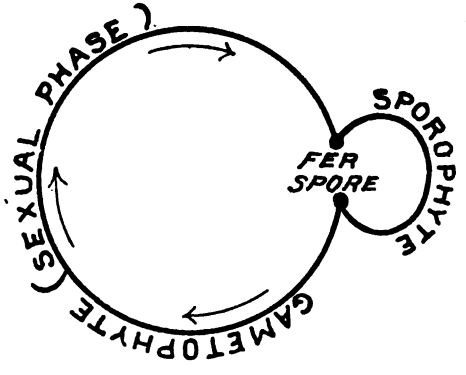
I. Among forms whose only method of reproduction consists of fission, in which the individual life begins with the completion of the karyokinetic process of cell division and closes when its individuality is lost in the next generation produced, the type of the life history of the organism may be represented by a straight line whose terminations bear no relation to each other. There is no round of life history, no cycle of development where fission is the law of reproduction.

II. Among forms in which conjugation occurs, we have successive stages of distinct sexual reproduction occurring before the

idea of bisexuality has been differentiated. Two purposes seem involved in this process: (1) The increase of vitality by the union of elements of separate origin; and (2) The production of a structure capable of holding vitality more certainly through critical changes of environment—hence the resting-spore. We have here a type of life history where continuity commences to curve into a circle and its end begins to unite to form a complete cycle of development. In many forms, however, the individual is too hopelessly entangled in colony life to be clearly separated.

III. In forms (like *Vaucheria*) where the sexual cells are clearly distinguishable from the early commencement of the process of reproduction, and the oöspore results directly and simply from the act of fertilization, the life history of the plant may be clearly said to be represented by the circle. The phase of growth is purely a sexual one from spore to germinating filament through the production of sexual apparatus to spore again. If asexual reproduction occurs, it merely serves to multiply the plant rapidly when favoring environment makes it possible, and bears no relation to the sexual process and is not dependent upon it.

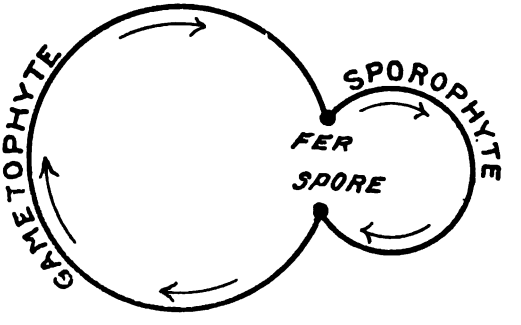
IV. Among some of the higher Algæ occur the simplest forms of alternation of phases of reproduction. While there are various modifications of the process in minor details, in many groups of



Algæ, the act of fertilization in certain representative forms is followed (1) By the formation of a special envelope of cells about the oögone, as a specialized protective covering; and (2) By the division of the cell contents of the oögone into a series of reproductive bodies — an asexual process following as a result of a

sexual one and therefore dependent on it. The life history here, instead of representing a simple cycle of growth, can be best characterized as a combination of two loops each short of a circle; the larger representing the sexual stage from germinating spore to the completion of the process of fertilization, and the smaller representing the asexual phase involved in the internal cell division that results in the development of the reproductive bodies. The so-called "alternation of generations" which is nothing more than the succession of phases in the life history of the organism, commences at a point considerably below the lowest Bryophytes.

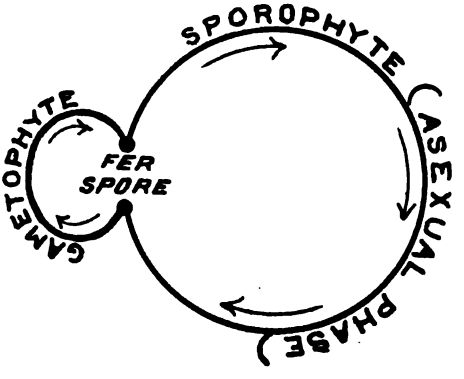
V. The transition from the above condition to that which we find in the lowest Archegoniates is a simple one. The advance manifests itself in the following particulars: (1) In the protective envelope of the egg cell being developed prior to the act of fertilization, and not as a result of it; (2) In the somewhat more complex development of the asexual phase (*sporophyte*) in the formation of a definite multicellular wall and the division of the interior by a double process of cell multiplication. Most of these



details even are more or less feebly foreshadowed in some of the higher Algæ. The only modification necessary in the diagrammatic representation of the lower Bryophytes, as contrasted with that of the higher Algæ, is the relatively greater development of the asexual phase which is therefore represented by a proportionally larger loop. The lines of specialization which have resulted from the varied differentiations of this simple type will be discussed more in detail later in this paper.

VI. The highest development of the principle of alternation

of phases of reproduction is illustrated by the well-known climax reached among the Pteridophytes in which the asexual phase represents a degree of specialization utterly disproportionate to the simple sexual phase (prothallus) which has scarcely advanced beyond the primitive condition reached by the lowest Archegoniates. The diagrammatic representation of the life history of the fern is therefore a reversal of that of the higher Algæ—the larger loop representing the highly differentiated asexual phase (sporophyte) and the smaller the simple thallose sexual phase (gametophyte).



The high degree of differentiation of the asexual phase of the Pteridophytes coupled with the great antiquity of the group has rendered them a stumbling block to many who have not been careful in tracing their homologies. In the evolution of the Pteridophytes, however, it must be remembered that the line of descent must be sought, not in a comparison of the sporophyte, so highly developed in the one so poorly developed in the other, but along the line of the simpler gametophyte. When we consider this feature of the development in its proper light, the progress of evolution from alga to fern is greatly simplified and the distance between the groups either in the time necessary for the derivation of the one from the other or in the slight degree of differentiation manifest in these coördinate phases, is reduced to a minimum. From higher algæ to simple prothallus the transition is not a difficult one. In regard to the other feature of the problem, it may be suggested that the develop-

ment of the sporophyte of fern-like plants, which dates back to the Devonian and reached a high degree of specialization in the Carboniferous, may have been strongly influenced and perhaps rapidly evolved by the peculiar environment of precarboniferous times; at least the statements of the books, in reference to the excessive amount of carbonic oxide in the atmosphere being peculiarly adapted to the growth and development of the lower Pteridophytes, would support such a hypothesis. On this point, however, it may be questioned whether the statements of the books do not need some modification.

I have said that the Hepaticæ have undergone a triple differentiation. Commencing with a simple thallose plant with its unmodified sporogone, it is evident that there are three possible lines of specialization: (1) The development of the thallus as such; (2) The transformation of the thallus into a leafy axis combined with the modification from creeping to ascending or erect habit; and (3) The specialization of the sporogone at the expense of the thallus. Even a cursory acquaintance with the diverse structures that are developed in the group will make it evident that the Hepaticæ have improved their opportunity in each of these three possible lines and have carried the differentiation of each line to a high degree of perfection. Let us follow out in some detail these three lines of development.

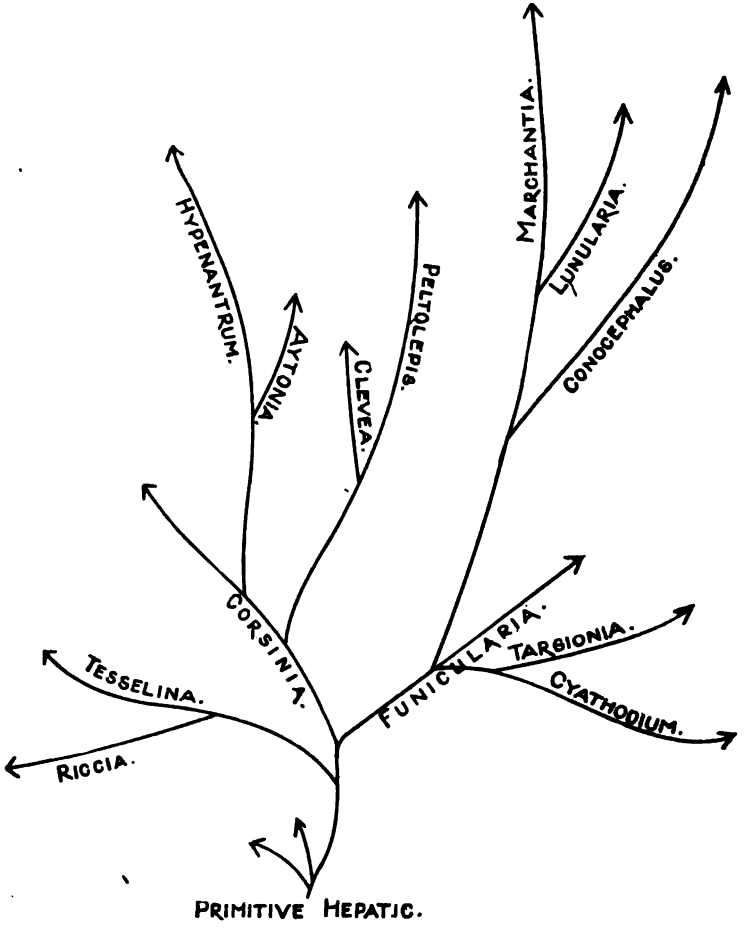
1. *The Marchantiales.* We must place as lowest in the series the group which commences with such simple types as Riccia and Tesselina and ends with the elaborate Marchantia and its congeners. Among the lowest types the habit is not greatly different from that of the Algæ, the plants either floating in water or attaching themselves to wet soil. The capsular development in the lower forms moreover is not very diverse from that of certain of the higher Algæ, the sporogone being without stem and often imperfectly surrounded by a capsular wall. As we advance to higher forms, we find not only an extensive modification of the thalloid structure necessitating an elaborate system of stomata and in many cases specially modified branches for the better accommodation of the reproductive bodies, but also a striking advance in the capsular development in which the egg cell develops not only a capsule or fertile portion, but also a stalk or sterile portion which, with the addition of elaters formed within the capsule, better serves to distribute the spores.

We may note here also two types of differentiation in the specialized branch that bears the sporophytes as it explains some seeming anomalies in the fruiting habits of some of our common *Marchantiaceæ*. The impression has prevailed and is now widespread that while *Marchantia* may commonly be found in fruit, *Conocephalus* rarely produces it. The fruiting branch of *Marchantia* is developed before the maturity of the sporogone is reached. This branch is therefore firm and consequently persistent. The botanist who only rarely comes in contact with plants except as they are preserved in herbaria or imbedded in celloidin, has considerable opportunity to see the spore-bearing branches of *Marchantia* as they are developed long before the spores are mature and persist long after the spores are scattered. On the other hand, *Conocephalus* whose archegones are fertilized during the late summer or early autumn, matures its capsules within the specially modified branch before this structure elongates as is thus rendered conspicuous. In this condition it passes the winter and with the earliest return of spring the reserve material of the thallus rapidly aids in sending up a semi-hyaline slender branch which lasts barely long enough to allow the capsules to burst through their calyptræ and then withers away. By the time the spring botanist, roused from his hibernation, goes forth to search for *Anemone* or *Epigæa*, *Conocephalus* has long since scattered its spores, its fruiting branch is withered, and the late observer concludes that it rarely produces fruit. He who will become a botanist in any broad sense must come in contact with nature face to face at all seasons, and study plants as they grow, as well as in the herbarium and laboratory. The man who sees and studies plants *only* as they are represented by dried herbarium fragments or in accordance with the stereotyped formula, "treated with a one per cent solution of chromic acid, stained in mass with picrocarmine, imbedded in paraffine and cut with a Minot microtome," is sure to get a one-sided notion of the true homologies of the vegetable world.

While all the minutiæ of the relations of the Marchantiales have not been worked out, the following provisional arrangement will give some idea of their affinities.

From simple forms like *Riccia*, themselves doubtless a considerable advance over the primitive hepatic, we find slight modifications in *Ricciocarpus* and *Tesselina*, and slightly more differentiated

forms in *Corsinia* and *Funicularia*. To the former are allied such higher forms as *Clevea*, *Aytonia* and *Hypenantrum*; from forms allied to the latter we have on the one hand *Cyathodium* and *Targionia* in which no specially modified branch is developed, and on the other,



Lunularia, *Conocephalus* and *Marchantia* which may be justly regarded as the highest thalloid development that appears among the Hepaticæ.

II. *The Jungermaniales.* The second line of differentiation among the Hepaticæ is in the direction of the formation of a leafy axis. From such thalloid forms as *Aneura* with a scarcely developed central axis to such simple modifications as appear in *Pallavicinia* and *Metzgeria*, in which the central axis becomes distinctly differentiated from the plain wing-like border a single cell in thickness, it is an easy step to pass to such pseudofoliaceous forms as *Schiffneria*, *Fossombronia* and *Haplomitrium*. From these forms again it is not difficult to pass to some of the simpler leafy axes like *Lophocolea*, *Bazzania* and *Jungermania*. It is in this group that we find the Hepaticæ attaining the greatest profusion of structure, the most remarkable diversity of foliar development, the widest range of adaptation, and the consequent abundance of genera and species that span the world from the lone and barren island of Kerguelen in the south, to the inhospitable region of Spitzbergen in the north. In this group some three thousand species have been developed, and judging from the rapidity of the returns, it is evident that the tale is not nearly told.

It is, of course, impossible, within the limits of the time assigned, to attempt to touch upon the numerous features of the evolution which this group has undergone in diverse quarters of the world; we can only hint at some of the more striking by way of illustration.

1. The protonemal development among the Jungermaniales is usually slight and ephemeral; in only occasional instances do we find it persistent. Perhaps the most striking illustration of this is in Protocephalozia, in which the formation of leaves occurs only as a special development for the protection of the reproductive bodies. The antherids are borne singly in the axils of rudimentary leaves while the perianth subtended by slender involucral leaves rises directly from the original protonema which represents the entire vegetative condition of the plant.

2. The lines of development leading from thallose to leafy forms are numerous among the Jungermaniales, and all of them have not yet been definitely correlated. Certain it is that there is no single line of thallose genera as distinct from the foliaceous ones. While the greater part of the thallose forms do not produce their fruit terminally, and hence may be separated into a distinct family, which may be called the *Metzgeriaceæ* from its typical genus, there are several instances in which thallose forms lead

up toward foliaceous forms with which they agree in the closer relation of sporophytic development, as well as in the more important fact that they bear the sporophyte terminal on the main stem or on a branch. The line of this character that is best known is, perhaps, that leading up to the Trigonantheæ from *Zoopsis* to *Cephalozia*. From the simplest thallose structure, differing only slightly from algæ, the various species of *Zoopsis* become developed so as to present the successive modifications of a leaf of a single cell, a leaf of two cells, and a leaf of four cells; from these steps the passage is easy to such simple two-toothed decurrent leaves as we see developed in some of the *Cephalozias*, especially in our common *Cephalozia multiflora*. The fruiting characters in this series are so strikingly alike that they have even been united in a single genus.

3. Perhaps no single group presents so many modifications in the diversity of foliar structure as is manifested in the various genera of the Jungermaniales. With nothing but leaf cells forming a more or less well developed lamina, the greatest conceivable variety of form coupled with modification arising from environment, has been differentiated, and we find numerous examples of marvellous adaptation of means to end. Among these we may note the simple tripartite leaves of *Blepharostoma* made up of simple rows of cells; the intricately divided leaves of *Trichocolea* and *Ptilidium* which give to the species of those genera their peculiar tomentose papearance; the ciliary fringes of endless variety that characterize the numerous species of *Plagiochila;* the median lamina of *Schistocheila* recalling a similar development in *Fissidens* among the true mosses, and above all the innumerable paraphyllia of *Stephaniella*, often covering the entire surface of the leaf. These merely indicate a few of the possibilities of the foliar development. In the leaf cells themselves, we have every grade of compactness varying from the lax structure of *Cephalozia*, *Chiloscyphus* and *Kantia* to the close compact structure of *Herberta* and *Gymnomitrium*.

But beyond all these are the various forms of complication of leaf clearly adapted to serve as retainers of moisture. From the simple folds in the leaves of *Radula*, *Scapania* and *Diplophyllum*, we pass to the basal pockets of *Lejeunea* which are sometimes elaborately differentiated, and the water sacs of *Jubula*, *Frullania* and more especially *Polyotus* in which they are sometimes developed in great profusion. As might be expected, these peculiar

foliar adaptations for holding moisture are most prominent in those species that have been driven from their normal habitation, the ground and on decaying logs, to the bark of trees and even the surface of leaves which in tropical countries are often wholly covered with various species of *Lejeunea*,[1] together with an occasional *Radula* and rarely species of other genera. The reputed symbiosis of rotifers and other small animals with these water sacs of *Lejeunea* and *Frullania* has been commented on by many observers.

4. No less remarkable is the development of the perianth which serves as a special protection to the maturing sporophyte. This is normally free from the uppermost stem leaves, which are usually modified from the ordinary form. In certain genera like *Nardia*, *Marsupella*, *Schistocheila* and *Harpanthus*, the perianth becomes more or less adherent to the involucral leaves and in some instances forms a bulbous or gibbous enlargement at the base. An exaggeration of this bulbous development produces the marsupiocarpous condition found in *Kantia*, *Geocalyx*, *Tylimanthus* and several other genera, in which the sporogone is developed at the base of a pendulous pouch which penetrates the substratum, or in the tropical *Tylimanthus* is hung among the stems of various mosses which grow in its vicinity. It is of interest to note that this condition has been developed independently in widely different sections of the family and cannot be considered as forming a tribal alliance by itself as was formerly maintained.

It must now be evident that the Jungermaniales, above all other Hepaticæ, are the types in which the most elaborate development has taken place and that they must furnish the typical representatives of this class. When we add to the great degree of differentiation, the widespread geographic distribution of the Jungermaniales which has resulted in populating almost every available island in the world, frequently with endemic species, it becomes evident that we must attribute a great antiquity to the group. The comparative absence of the hepatics in fossiliferous rocks, for obvious reasons, should count as little in determining their antiquity.

III. *The Anthocerotales.* Having considered the two groups in which the hepatics have disported themselves as such, we come finally to the group in which their development has looked toward

[1] I have only once found our *Lejeunea calcarea* in Indiana. In that instance, it completely covered a small leaf of *Camptosorus* growing in the damp moss of a ravine. This is the first instance known to me of *Lejeunea* growing as an epiphyte in northern latitudes.

something higher in the plant world. If the Marchantiales have elaborated the thallus at the expense of other parts, and the Jungermaniales have developed leafy axes and exhausted their energies in the elaboration of beauty and intricacy of foliar development, the Anthocerotales have found a more important line in which to differentiate, namely, the development of the sporogone; and while it has resulted in small returns when considered from a hepatic standpoint, the results otherwise are commensurate with the whole range of higher plants from Mosses to Compositæ.

In the Anthocerotales, the thallus has undergone a slight differentiation from the primitive type; the sporogone, however, develops into a fleshy structure that frequently requires stomata for its transpiration processes. The capsule is necessarily a somewhat permanent structure and, unlike all other Bryophytes, develops its spores continuously from above downward.

The ancestors of *Anthoceros* and *Notothylas* on the one hand and the Musci on the other, were doubtless the same, and the line of separation between them probably commenced at an early day, since the elaboration of genera and species is no less marked in the Musci than in the foliaceous Hepaticæ.

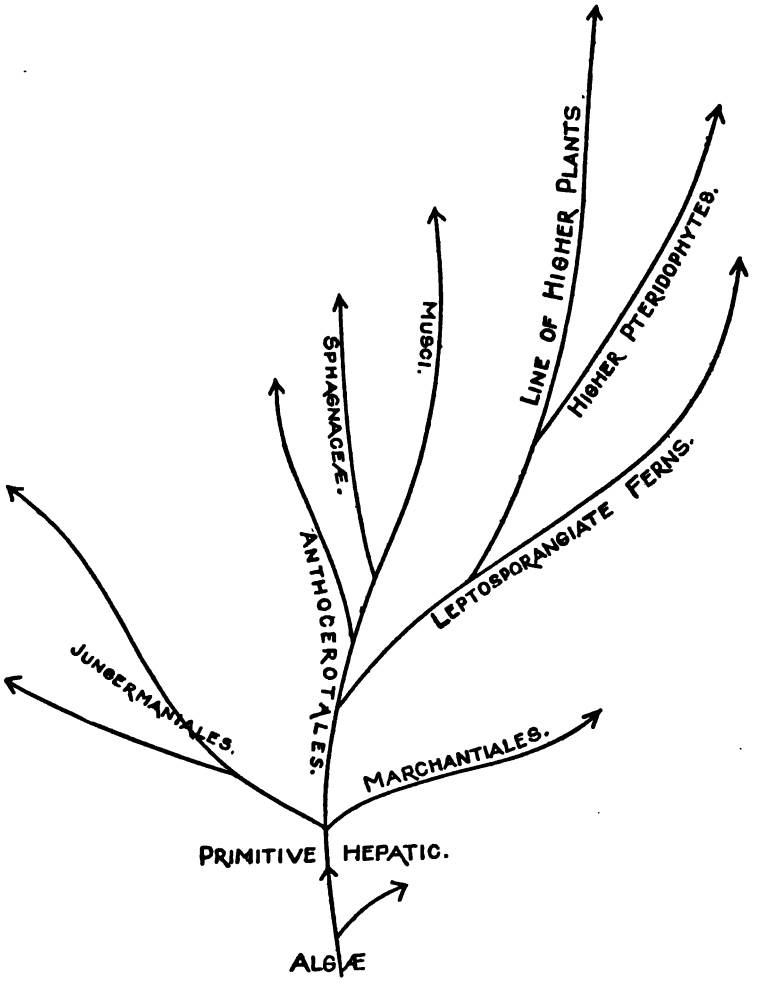
It has also become evident that the line of development of the leptosporangiate ferns, leading upward to the line of the higher plants, is to be sought as a branch from the primitive Anthocerotales. While more investigation is necessary in this direction the general relations may be indicated by the diagram on the page opposite.

The early forms of *Anthoceros* were not swerved from their purpose; they have continued the development of the sporogone at the expense of the thallus and to-day stand unique among the Hepaticæ. They differ as widely from all other members of the group as do the Musci and Sphagnaceæ and, for this reason combined with others, the class Hepaticæ has little reason for further existence in our system of classification. A reorganization becomes necessary as soon as the remaining Bryophytes can be properly coördinated.

We can then summarize the relations of the Hepaticæ:

1. The group is not of recent origin. This is shown not only from the widespread geographic distribution of its major group, and its extensive modification into diverse genera, but as well by its relations through the Anthocerotales to higher groups which have themselves a high antiquity.

2. The group is not a compact one, nor is it entirely circumscribed. The three groups of the Hepaticæ above outlined differ as much or more among themselves as the remaining Bryophytes differ from them. There is a necessity for a new grouping of the



Bryophytes to accord with our present knowledge. The present grouping into Musci and Hepaticæ as coördinate classes, is entirely unsatisfactory, and artificial.

3. In such a triple development as exists among the Hepaticæ, no single plant can stand as a type which will fairly represent the entire group. If a single plant is to be considered, however, it would be only fair to make the selection from the group which is at once the most highly specialized structurally and the most widely represented in all parts of the world. To the Jungermaniales, and not to the Marchantiales, belongs this distinction.

4. We must recognize at least five families among the Hepaticæ. From the Jungermaniaceæ, it is well to separate teose forms in which the archegone terminates the growth of the shoot from those in which the archegone is distinctively a lateral development. The "Jungermaniaceæ anakrogynæ" of Leitgeb and Schiffner, which will include many but not all of the "Jungermaniaceæ thallosæ" of previous writers, may well be separated as a distinct family for which we propose the name, *Metzgeriaceæ*. The older name, Jungermaniaceæ, may properly be retained for the remaining part of the family which includes by far the greater number of genera and species.

5. The Hepaticæ are specially interesting as constituting the connecting link in the evolution from thallophytes (algæ) to the higher plants. In this particular, the line of the Anthocerotales, in which mere vegetative function is sacrificed for the sake of reproductive function, represents the royal line of development.

PAPERS READ.

MOVEMENT OF GASES IN RHIZOMES. By KATHERINE E. GOLDEN, Purdue University, Lafayette, Ind.

[ABSTRACT.]

THE kinds and quantities of gases in plants have been the subjects of experiments by vegetable physiologists and chemists for over a hundred years, and recently the laws governing the entrance of gases into, and their passage in, plants are being investigated. Diffusion of gases is constantly taking place in plants, as it has been demonstrated that from 95–99% of the mass of plants is derived from the air, and that the air in the intercellular spaces is of a different chemical composition and at a different pressure from the atmospheric air. This difference in pressure and composition varies in proportion to the activity of the processes of assimilation and respiration.

The greater part of the gases in plants enters through the stomata and lenticels, these openings being connected with the intercellular spaces, which form a continuous system throughout the plant. In entering the gases follow the law of diffusion, or they pass through small openings in thin plates, the rate being as the square root of the density of the commingling gases. With regard to parts of plants not having stomata or lenticels, the gases can enter the plant only by diffusing through the cell-membrane, the velocity in this case depending on the coefficient of absorption and the density of the gas, but being modified by the chemical constitution of the vegetable membrane in question. Unlignified and unsuberized membranes, when in the dry condition, do not permit any appreciable amount of gas to pass through, while lignified and suberized membranes permit gases to pass through when the membranes are both wet and dry.[1]

The parts of plants used in the experiments were rhizomes, or underground stems, which are generally transversely geotropic organs serving the same purpose as thickened roots in having stored in them the nourishing material that is elaborated by their leaves. Their epidermis is free from stomata and lenticels, so that the gas found in them can originate from the epidermis only, this tissue absorbing the gas from the surrounding air. The rhizomes used were Mentha piperita, Helianthus grosse-serratus, Solanum tuberosum, and Mimulus moschatus. The epidermis of the plants used was found to be unlignified and unsuberized, the outer walls of the cells thickened and packed closely together so as to form an imperforate membrane. The inner tissue was made up nearly entirely of

[1] Wiesner, J., and Molisch, H. Untersuchungen über die Gasbewegung in der Pflanze Sitzungsberichten d. Kais. Akad. d. Wiss., Wien, Bd. XCVIII., Abth. I., 1889, pp. 24–38.

parenchyma, having large intercellular spaces through which gases, after gaining access to the interior of the plant, could very readily permeate.

Experiments.

1. To determine pressure of gases in, and rate of passage of gases through definite lengths of, rhizomes.

To determine the first point a large number of rhizomes were cut under water, and in the majority of cases bubbles of gas rose through the water from the cut surfaces, showing that the air was at a greater pressure in the interior than the atmosphere.

To determine the second point, vigorous looking mint rhizomes were spaced off in lengths of 20, 10, 5, 3, and 2 millimeters, and the cuttings made at intervals of 20 seconds; bubbles of gas were given off at every cutting. Then a number of spaces of 1 mm. were marked off, this being the shortest distances that could be cut readily under water with any degree of accuracy, the intervals of time being varied from 1 to 2, 2½, 3, 5, 7, 11, 17, 20 minutes; bubbles of gas were given off each time, but becoming smaller as the time was prolonged between the cuttings. The next interval taken was 25 minutes, and at the end of that time no discernible amount of gas was given off. These experiments show that for the pressure of the gases in 1 mm. of the rhizome to become the same as the pressure of the atmosphere required between 20 and 25 minutes.

Some experiments on the same point but of a somewhat different character as to arrangement were also tried. A piece of mint rhizome was fastened in a glass tube by means of a rubber stopper; the tube was then filled with mercury, this being kept in place by means of a stopper until the tube was fastened in place in a vessel of mercury. A short piece of glass tube was placed round the first tube, so as to hold mercury over the rubber stopper through which the stem was placed, in order to prevent the passage of any gas through it. The following table shows the time taken by the mercury in falling the indicated distances.

Rhizomes, 3 internodes; length 75 mm., cross-section 6.25 sq. mm.

Time in minutes.	Distance in mm.
2	44
4	66
6	76
8	85
10	91
12	96½
14	102½
16	108½
18	114
20	119
22	124½
24	129
26	133
28	137
30	141

Further measurements were not taken, as the air passed through more and more slowly, it being 22½ hours before the mercury in the tube came to a level with the mercury outside, a distance of 357 mm.

Two other experiments of the same kind, but the rhizomes of different lengths and cross-sections, were tried to determine if the length of stem were a factor in the rapidity with which the air passed through the stem. Readings were taken at intervals of 5 minutes.

1. Rhizome, length 102 mm., cross-section 6.25 sq. mm.
2. " " 48 " " " 5.29 " "

	1	2
Time in minutes.	Distance in mm.	Distance in mm.
5	10	12
10	16	20
15	21½	28
20	27½	35
25	33½	42
30	39	48½
35	48	55
40	47	61
45	50½	65½
50	58½	71
55	56½	76½
60	60	81½
65	63½	85½
70	66½	89½
75	69½	93½
80	72	98
85	76	103
90	80	106½
95	83½	111½
100	87	116

2. To determine passage of gas through section of epidermis of rhizome under pressure.

A section of the epidermis of grape was cleaned thoroughly and fastened with sealing wax to the top of a piece of glass tubing, 445 mm. long and 5 mm. diameter. The tube was then filled with mercury and placed in a vertical position in a vessel of mercury. The epidermis held up the column for nine days with but slight variations in its height, these variations being due to the changes of temperature and of barometric pressure. In the meantime the membrane had become concave from the pressure upon it of the outside air. The same experiment was repeated with like results, the length of the tube being varied. A cross-section of cork .5 mm. in thickness was used next, the section being fastened to a tube 785 mm. long and 5 mm. diameter. This held the column of mercury up for about a month; then the mercury began to drop very slowly. After 55 days the apparatus was taken down, the mercury in the mean time having dropped 99 mm., but the section was still intact, though it had

become concave from the pressure of the air. This experiment was also repeated, the result being practically the same in every case.

Then a section of the epidermis of mint rhizome was fastened on the end of a glass tube, 102 mm. long and 5 mm. diameter, in the same manner as in the former experiments, and the tube filled with mercury. The mercury remained at the original height for three days, then fell gradually. This was repeated with other lengths of tubes with practically similar results. The mint was hard to manage for long lengths of tubes as the pressure of the mercury ruptured the sections. This prevented as high pressures to be used as with the cork, but enough was done, however, to prove conclusively that gases under pressure could not pass through the epidermis.

3. To determine amounts of diffusion of gases without pressure through living plant, and dead plant and animal membranes.

Hog's bladder.		Mint epidermis.		Mint epidermis, dead.	
Time in hrs.	Am't gas, cc.	Time in hrs.	Am't gas, cc.	Time in hrs.	Am't in gas, cc.
22¼	1.154538	19¾	8.078765	18	4.272576
46¾	1.919230	26½	8.832752	42	2.110624
70¼	2.309076	43	5.466384	65	4.272576
94¼	3.463614	75¾	6.346304	73¾	5.277888

In these three experiments, hog's bladder, a section of living mint epidermis, and a section of mint epidermis that had been killed by placing for a few seconds in water at 75° C., were fastened on the ends of tubes, the tubes then filled with water and set in vessels of mercury. The water in the tubes was displaced by carbonic acid gas, the conditions in the three being made as nearly alike as possible. The results show that while there was a considerable amount of diffusion in all three, that of the living plant membrane had the greatest rapidity, so that the living plant must be able to dissolve the gas more readily than the others. Where membranes, either plant or animal, are used, the membranes dissolve the gas on one side, and, when saturated, evaporate it from the opposite side, so that there is a kind of solution taking place all the time. With membranes of this kind, the rate of diffusion depends not only on the density of the gas, but also on its relation to the chemical composition of the membrane.[1]

All the membranes were kept moist in these experiments, which is very probably the reason diffusion took place to such an extent, as dry membranes are but slightly permeable by gases. In another set of experiments with similar conditions, with the exception that the membranes were kept dry, the hog's bladder and living mint membrane allowed a small amount of diffusion, while the dead mint membrane allowed none whatever.

[1] Kimball, A. L. Physical Properties of Gases, 1889. p. 135.

4. To determine rate and amount of diffusion of gases through both epidermis and internal air cavities.

In the next set of experiments that were undertaken, pieces of the rhizomes were used. In these there are two sets of movements of the gases; a molecular one when the gases are passing through the imperforate epidermis, diffusing through the cell-sap, or permeating the protoplasm; a movement of the masses of gases when they fill the intercellular spaces, vessels, and air cavities. In the former case the rate of diffusion depends on the coefficient of absorption of the gas by a particular cell-fluid, on the molecular condition of the cell-wall, on the temperature, and on the pressure of the air (Formula: $\frac{c}{\sqrt{d}}$ c coefficient of absorption, d density of gas); these being constantly disturbed by the metamorphosis of substances in the plant, caused by chemical transpositions. In the latter case the rapidity of movement in the cavities varies in proportion to their size (Formula: $\frac{D^4}{l}$, D diameter of tube, l length of tube), and the cavities are being varied in size, constantly by the changing conditions of turgescence of the enclosing cells. Thus there are two sets of conditions in which are factors that are uncontrollable, so that the laws governing gases, when taken in connection with inert matter, cannot be applied without modifications.

In the following experiments the conditions were made as nearly uniform as possible, as far as the fastening the sections in the tubes, the kind of tubes, and the moisture conditions were concerned. But different lengths of rhizomes were used, and sometimes the growing end, as this did away with the necessity of using sealing-wax. The method used in each case was to place the piece of rhizome used (after closing the end that was to extend into the tube with sealing-wax, if it were not the growing end) in a perforated rubber stopper that fitted air-tight into the end of a glass tube;[1] then a small piece of rubber tubing was fitted outside the same end of the glass tube, in order that a short piece of glass tubing might be placed round the glass tube that held the rhizome. The glass tube was then filled with water[2] and placed in a vertical position in a vessel of mercury; the water was then displaced by the gas. A layer of mercury and a layer of water were placed in the outer glass tube and covering the rubber stopper that held the rhizome, the mercury being used to prevent diffusion of the gas through the stopper, the water to keep the rhizome moist and to prevent injury from the mercury. Observations were then taken of the height of the column of mercury as it rose in the tube, the temperature, the time, and the barometric pressure.

The following experiment is given as an illustration of the method employed in determining the amount of diffusion in the various experiments.

A piece of mint rhizome was used consisting of 2 internodes 38 mm. long and approximately 6.25 sq. mm. cross-section — the rhizome not being perfectly circular — this was fastened in a glass tube 385 mm. long and 38.5 sq. mm. cross-section. The formula used for finding corrected volume of gas was

[1] The size of the tube used can be found in the tables on diffusion.

[2] Water was used to fill the tube instead of mercury, as it exerted much less force against the rhizome. The mercuric fumes were injurious.

$$v' = \frac{(b - b_1 - b_2)\ v}{1 - 0.00366\ t^\circ}$$

in which v' is volume of gas reduced to $0^\circ C.$ and pressure of 1m. of mercury, v the volume of gas, b the height of the barometer, b_1 the height of the column of mercury above the level of the outer dish, b_2 the tension of aqueous vapor, t the observed temperature, and 0.00366 the coefficient of air.[1] The gas used was carbonic acid.

Observation.	Time in Minutes.	Vol. of gas in cc., corrected.	Amt. diffusion in cc. from corrected vol.	Vol. of gas in cc. uncorrected.	Amt. diffusion in cc. from uncorrected vol.
1	0	10.018821	0	14.8166	0
2	120	9.335745	.683078	14.2393	.5773
3	360	8.761502	1.257319	13.8545	.9621
4	1320	6.999112	3.019709	11.8533	2.9633
5	1825	6.299231	3.719590	10.9296	3.8870
6	2725	5.033476	4.985345	9.2363	5.5803
7	4165	3.884857	6.133964	7.7354	7.0812
8	5630	3.235881	6.782940	6.7783	8.0433

In obtaining the corrected volume of the gas, the error of the meniscus was disregarded, as it made but a very slight difference in the results. In comparing the results of the corrected and uncorrected volumes, the uncorrected volumes give very fair approximations of the amounts of diffusion which took place, so that in the following tables the uncorrected volumes are given, as the slight differences between them and the corrected volumes would not affect any conclusions that might be drawn from the results.

In the following tables no attempt has been made to give the number of observations that have been taken on the experiments, but to show the maximum point of diffusion, and the time required. It will be seen that the maximum amount of diffusion varied very considerably as well for the same as for different plants, and also the time required to reach that point.

The attempt was made in each experiment in fastening the rhizome in the tube to place it so that half of it extended into the gas, the other half into the air. This would give, in every case, a diffusion surface of about half of that indicated by the figures in the tables. The air into which the rhizome extended was kept moist by a layer of water over the mercury.

Comparing the results of the tables for diffusion of carbon dioxide and hydrogen, we see that the greater amount of diffusion of the carbon dioxide took place, and this gas had the greatest rapidity also. The largest amount of the carbon dioxide diffused being 9.891 cc. in 190¼ hours against 4.128 cc. hydrogen in 264

[1] Bunsen, R. Gasometry, p. 88.

hours, the amount of diffusion surface being about the same in each case. The ammonia caused the rhizomes to turn black, as it killed the tissue, so that any comparison between the action of this gas and the others could not be made. The diffusion of gas through the entire rhizome was very rapid, for in sixty minutes from the beginning of the experiment the water around the part extending into the air gave an alkaline reaction.

DIFFUSION OF CO_2.

No.	Name of plant.	Length of tube in mm.	Diameter of tube in mm.	Length of rhiz., mm.	Diameter of rhiz., mm.	Time in hours.	Max. height of mer. in mm.	No. cc. gas diffused.
1	Helianthus grosse-serratus	185	7	28	2.7	94½	31	1.198
2	" " "	102	7	19	2.5	45¾	96	3.695
3	" " "	317	6	30	2.5	94½	296	8.369
4	Mentha piperita	685	7	51	3.0	66	26	1.001
5	" "	456	4	28	3.0	49¾	23	.289
6	" "	684	7	87	8.5	144	126	4.849
7	" "	385	7	29	3.0	190¼	257	9.891
8	" "	218	6	30	3.0	478	113	3.195
9	Solanum tuberosum	380	7	15	2.0	141¾	53	2.040
10	Mimulus moschatus	216	5	14	2.0	191¼	14	.275
11	Hog's bladder	126	7	0	7.0	408	21	.808
12	" "	255	7	0	3.0	408	30	1.155
13	Control, rubber stopper	126	7	0	7.0	144	0	0.000

DIFFUSION OF H_2.

1	Mentha piperita	390	7	25	2.5	190	25	.952
2	" "	250	7	34	2.0	142	23	.885
3	" "	252	7	28	2.0	17¾	15	.778
4	" "	245	7	26	3.0	46	33	1.270
5	" "	255	6	32	3.0	255¾	60	1.696
6	" "	323	6	30	3.0	264	146	4.128
7	Solanum tuberosum	387	7	24	2.0	166¼	34	1.308
8	Mimulus moschatus	247	6	16	2.0	190¾	20	.565
9	Hog's bladder	255	7	0	3.0	461	40	1.539

DIFFUSION OF NH_3.

1	Mentha piperita	384	7	40	3.0	70	62	2.386
2	" "	384	7	42	3.0	1½	334	12.854

In taking frequent observations upon the experiments, it was observed that the mercury was subject to fluctuations in those with hydrogen, sometimes dropping to the level of that in the vessel outside Those with carbon dioxide,

however, rose steadily, showing no fluctuations whatever. It was also observed that when the temperature was low the mercury column rose much more rapidly than with high temperatures, both for the carbon dioxide and hydrogen. This may be due to the fact that a rise in temperature causes an expansion of the gases, and they would, consequently, exert a greater pressure against the membrane; and as gases will not diffuse through unlignified and unsuberized membranes under pressure, it may be that the small extra pressure hinders diffusion to some extent.

From the results of the experiments it is apparent that the individual plant membrane is of the greatest importance in the diffusion of gases; for in experiments 7 and 8 in the table of diffusion of CO_2, the rhizomes had the same diameter, nearly the same length, and were the same kind of plant; yet experiment 7 gives a diffusion of 9.891 cc. in 190½ hours against 8.195 cc. in 478 hours by experiment 8. The same thing is also apparent in the other experiments. The limit of diffusion was much less in the musk and potato than in the mint and sunflower, the mercury in no case rising as high for the former as for the latter, showing that the membranes of mint and sunflower must have a greater attraction for the gas, since they allowed its more rapid penetration.

In the experiments the conditions in regard to the position of the CO_2 were reversed, normally a plant is in an atmosphere containing but about .04% by volume of CO_2, and containing within it from about 3.40 to 6.38% in sunlight, and from 14.99 to 21.51% in the dark,[1] whereas in the experiments the rhizomes were in an atmosphere composed entirely of the CO_2, but the experiments showed that the membranes acted as they do normally in the plant, that is, to allow the CO_2 to diffuse through them from the side having the greater volume to that having the lesser, just as the osmosis takes place in the process of respiration. For as there is no chlorophyll in the rhizomes, no decomposition of the CO_2 takes place. The starch in the rhizomes being formed not from the presence of CO_2, but from the dissociation of the layers of protoplasm during the metabolic processes.

In the experiments with H_2 the same thing took place as with the CO_2, the gas passed from the side having the greater volume to that having the lesser.

[Read in joint session of Sections F and G.]

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[1] Johnson, S. W. How Crops Feed, p. 46; quoted from Phil. Trans. 1861, II. p. 486.

LIMITS OF BIOLOGICAL EXPERIMENTS. By Dr. MANLY MILES, Lansing, Mich.

[ABSTRACT.]

THE proposition to test theories in evolution by direct experiments on living organisms which has been favorably noticed, and the numerous futile feeding experiments that have been made at the government experiment stations, raise the question as to the probable limits of direct experimental methods in dealing with biological problems. "The whirligig of time," in connection with a certain uniformity in the outcome of the modified processes of nutrition and reproduction in a number of individuals, must be regarded as essential elements in bringing about the gradual aggregation and perpetuation of the minute changes in living organisms which we recognize as processes of evolution.

Aside from these significant factors, which cannot be neglected, the exceedingly complex conditions involved in all biological activities appear to be formidable difficulties to overcome in attempting a direct verification of theories relating to the various agencies concerned in evolution, or in determining the relative value of foods in the processes of nutrition.

Intelligent breeders of domestic animals have no doubts in regard to the heredity of acquired characters, which, in the light of their experience, they look upon as a fundamental principle in stock breeding, and one of the most important factors in the available means of improvement. The direct proof of this principle by experimental methods must, however, be difficult, if not impossible, notwithstanding the cumulative and apparently conclusive evidence presented in the history of the improved breeds, and the experience of successful breeders who have recognized its importance in the improvement of their animals.

The dominant influence of other known biological factors may completely obscure well-marked special characters that have undoubtedly been inherited, as in the familiar facts of atavism, and they must effectually prevent the detection of the initial stages in the development of any new characters under investigation, which may in fact have been potentially transmitted for a number of generations.

Reversion, prepotency, and the influence of a previous impregnation are conspicuous obstacles in the way of tracing the immediate or incipient indications of the inheritance of any particular acquired character which it may be desirable to perpetuate by judicious selections.

In many of the arguments relating to the heredity of acquired characters it appears to be tacitly assumed that each particular character is transmitted as an entity, regardless of its interdependent relations to other parts of the organism, and especially with the specific functional adaptations of the organs of nutrition which have made its development possible. As pointed out in a paper read in Section F at the Rochester meeting of the Association, physiological changes in the organism must precede any manifest modification of structural characters, and the transmission of a morphological peculiarity must therefore involve the transmission of the functional activities through which it has its origin. It was also shown that a habit, or bias, of the nutritive processes in a certain direction may be transmitted for a number of generations without any

visible morphological evidence of its existence, and that, in the lapse of time, it may lead to the development of obvious structural changes that are recognized as new characters. Experimental methods in biology are too crude to admit of a recognition of these preliminary steps in the development of new characters, which must be taken into account in making a satisfactory verification of any of the processes of evolution.

The artificial conditions to which our domesticated plants and animals are subjected intensifies their susceptibility to variation, and there appears to be a constant tendency to reversion when any unfavorable conditions prevail in their treatment. Under ordinary management, repeated systematic selections are necessary, in order to maintain the highest development of the most desirable characters, and a considerable number of individuals will be required to make any marked improvement in special qualities, as all do not respond alike to the artificial modifying conditions of their environment.

There are also individuals that retain a tendency to the prepotent transmission of the old race characters, notwithstanding the high development of the particular improved characters they possess, and a pedigree showing that all known ancestors have had the desired qualities is looked upon as a valuable index of the dominant inherited characters.

Even the best established breeds fail to exhibit the uniformity in their general characteristics that prevails in wild species that have been subjected to the more rigorous and discriminating process of natural selection. The methods of artificial selection in the breeding of animals are lacking in the inexorable consistency and comprehensiveness that characterize natural selection. The breeder of improved animals is unable to perceive all of their innate and acquired physiological tendencies, and his selections are made with reference only to the most obvious peculiarities or qualities, and he overlooks and neglects many of the factors concerned in determining the correlated relations of the sum of their characters.

Feeding experiments to ascertain the relative nutritive value of different articles of food, and the advantages of different methods of feeding, or to determine the relative merits of different breeds, are especially liable to mislead from the complexity of the problems presented, the small number of facts under observation, and the practical difficulties in the way of tracing the obscure relations of the most significant factors in the phenomena under investigation, to say nothing of the fallacious and obsolete chemical theories of nutrition that are too often adopted in a popular discussion of the results.

It is not my purpose to enter upon an exhaustive discussion of the limits of experimental biology, but to point out some of the practical difficulties involved in its methods and results. Without further reference to particulars, it must be evident that biological activities have such complex interdependent relations that theories relating to evolution cannot be verified, or practical problems in nutrition satisfactorily solved, by direct experimental methods.

[Read in joint session of Sections F and G.]

THE GROWTH OF RADISHES AS AFFECTED BY THE SIZE AND WEIGHT OF THE SEED. By Prof. B. T. GALLOWAY, U. S. Department of Agriculture, Washington, D. C.

[ABSTRACT.]

THE relation of the weight of the seed to the weight of the product is considered, and the physiological questions involved are discussed. It is shown that if large seed is used about 90 per cent of the crop reaches marketable size at the same time, while if mixed seeds are used, or seed as it usually comes from the market, only about 45 to 50 per cent of the crop matures at the same time. In other words, if large seed is used 90 per cent of the crop will mature in from thirty-five to forty days, while if large and small seed are used only about 50 per cent of the crop will mature in this time.

[Read in joint session of Sections F and G.]

SIMPLIFICATION AND DEGENERATION OF STRUCTURE IN THE ANGIOSPERMS. By Prof. CHARLES E. BESSEY, Lincoln, Nebr.

[ABSTRACT.]

ILLUSTRATIONS of simplification of structure in Calycifloræ (*Umbelliferæ*) and Inferæ (*Compositæ*). Illustrations of degeneration in the Dodder (*Cuscuta*), Mistletoe (*Phoradendron* and *Arceuthobium*) and Broom-rapes (*Aphyllon*, etc.).

FURTHER STUDIES IN THE RELATIONSHIP AND ARRANGEMENT OF THE FAMILIES OF FLOWERING PLANTS. By Prof. CHARLES E. BESSEY, Lincoln, Nebr.

[ABSTRACT.]

DISCUSSION of the primitive flower of the Monocotyledons. Modifications of the primitive flower by increased complexity of structure. Modifications by simplification of structure. Origin of Sedges and Grasses. Development of Irises and Orchids.

Discussion of the primitive flower of the Dicotyledons. Modifications by increased complexity. Modifications by simplification. Development of the Bicarpellatæ. Development of the Inferæ. (The paper was accompanied by a wall chart.)

THE SUGAR MAPLES OF CENTRAL MICHIGAN. By Prof. WM. J. BEAL, Agricultural College, Mich.

[ABSTRACT.]

1. A brief description of the species *A. barbatum* Michx.
2. A brief description of the black variety *A. barbatum nigrum* Sargent.
3. Showing that *A. saccharum barbatum* Trelease is not a variety even, as it grows on the tops of numerous trees of the species.

4. Give a summary of comparisons by measurement of leaves, fruit and other points of some eighty trees, showing that the (*a*) color of older branches and stems is no criterion of the species or variety, but is due to lichens and other fungi; (*b*) shape of top not specific nor varietal; (*c*) that width of petiole of base is of value; (*d*) there are intermediate forms between the species and variety; (*e*) the number of lobes of leaves is not varietal; (*f*) the shallow sinuses is not a reliable distinction, as the fullest sinuses seen, happen to be in leaves of the species; (*g*) trees of the species sometimes bear most of their leaves with the sides drooping, or limp, as is more often the case with the variety. Leaves of the variety are often flat, or some with edges turned up; (*h*) the thickness of both are carefully measured; (*i*) shape of fruit, size, length, angle of divergence of wings, etc., compared.

Specimens exhibited confirm the statements made.

SOME AFFINITIES AMONG CACTACEÆ. By Prof. JOHN M. COULTER, Lake Forest, Ill.

[ABSTRACT.]

THE relationships among Cactaceæ are so intricate that their systematic study is beset with unusual difficulty. A recent study of our species of *Cactus* (*Mamillaria*), *Anhalonium*, and *Lophophora*, in the field and in cultivation, has suggested certain lines of evolution which seem worthy of notice. The characters in question have to do with the relative position and structure of tubercles, spines, and flowers. In the discussion, the two subgenera of *Cactus* (*Eumamillaria*, and *Coryphantha*) are considered separately. *Eumamillaria* is characterized by its grooveless tubercle, which bears at its summit the spine-bearing areola, and in its axil the flower-bearing areola. *Coryphantha* shows the same relative position of the two areolæ, but they are connected by a deep, woolly groove running down the upper face of the tubercle; in fact the two areolæ seem to be but expansions of this groove at its extremities. In *Echinocactus* the two areolæ become contiguous at the summit of the tubercle. The relation between *Coryphantha* and *Echinocactus* is made evident by intermediate forms, in which the groove gradually shortens, making the flower areola more and more extra-axillary, so that it is seen to gradually ascend the tubercle until, reaching its summit and becoming contiguous with the spiniferous areola, the resulting form is an *Echinocactus*. Whether the groove has gradually shortened or gradually lengthened is not clear, but the indications are that the *Echinocactus* condition has given rise to *Coryphantha*, and that in turn, by the closing of the groove, to *Eumamillaria*. Related to these forms are two aberrant genera, now regarded as such, but frequently variously referred to *Cactus* (*Mamillaria*) and *Echinocactus*, viz., *Anhalonium* and *Lophophora*. The real affinities of these two genera become evident upon a study of their growth. The very young tubercles of *Anhalonium* are those of *Coryphantha*, such as *Cactus macromeris*, with the flower-bearing areola extra-axillary, the woolly groove extending about half way down the tubercle. In later development, however, the upper and lower portions of the tubercle be-

come much modified, and very different from each other, the upper portion becoming a very thick triangular bract, in some cases preserving the woolly groove, in other cases the groove being obliterated and appearing only as a minute tuft at the tip of the bract, and in all cases the spine-bearing areola being completely obliterated. It seems evident that *Anhalonium* is an offshoot from forms intermediate between *Echinocactus* and *Coryphantha*. *Lophophora* has been still more puzzling, as it shows a grooveless tubercle upon the summit of which is the flower-bearing areola, suggesting at once *Echinocactus*, to which the forms have mostly been referred. However, the entire disappearance of a spine-bearing areola should suggest doubt. The very young growth of *Lophophora* suggests the explanation. Here again the young tubercle shows the flower-bearing areola below the summit, as in the young *Anhalonium*. But the small tip develops no further, while the floriferous areola becomes terminal by the large development of the lower portion of the tubercle into a broad mass, in the centre of which the floriferous areola appears as a small depression with a penicillate tuft of hairs.

In conclusion, in the group of forms under consideration, *Echinocactus* is suggested as the primitive form, with its grooveless tubercle bearing at summit the contiguous floriferous and spiniferous areolæ. The formation of a groove separating the two areolæ slightly at first, and finally carrying the floriferous areola to the axil of the tubercle, has given rise to *Coryphantha*, intermediate forms having given rise to the aberrant genera *Anhalonium* and *Lophophora*; while the closing of the *Coryphantha* groove has given rise to *Eumamillaria*. It may be that this evolution has proceeded in the opposite direction, from *Eumamillaria* to *Echinocactus*, but it would not change the relative position of the genera here suggested.

REGULATORY GROWTH OF MECHANICAL TISSUE. By Prof. FREDERICK C. NEWCOMBE, Ann Arbor, Mich.

[ABSTRACT.]

THE mechanical theory of growth still found in manuals on plant physiology never had sufficient basis in fact on which to rest, but supported itself on the following observations, the last two of which have been found to have exceptions: (1) Between all growing tissues both longitudinal and transverse tensions are present, the outermost seeking to contract, while the innermost are seeking to expand; (2) swaying of a plant promotes growth from the cambium; (3) ligatures about woody stems decrease the number and size of the xylem elements; (4) slitting the cortex longitudinally promotes growth from the cambium; (5) abrading the dead part of bark promotes growth from the cambium; (6) normal clefts in the bark of trees deepen in the early spring; (7) branches and roots of trees show eccentricity of growth, and the greatest growth is on the lower side, or when flexed, on the concave side; (8) in the curving of stems due to geotropism, heliotropism, etc., the greatest growth in thickness is on the convex side.

The weakness of this theory lay in the insufficiency of supporting observation and in the circumstance that two all-important factors were assumed in the argument, with but slight evidence for their validity. These two assumptions were, (1) that extension of cells is due wholly to stretching from the hydrostatic pressure of cell-contents; and (2) that the resistance offered by the cortex is great enough to control the amount and direction of cambium growth.

Both of these assumptions have been proven incorrect, the second by Krabbe, since he measured the resistance of the cortex in trees and found it without effect on the growth of the cambium; and the first by Pfeffer, since he has recently shown that membranes will grow to the very limit and probably beyond the limit of the pressure from within the cells.

The fall of this theory takes with it the explanation of cortical pressure in forming annual rings, eccentricities of growth, correlative increase or decrease of supporting tissue, and so forth. All of these phenomena, on which the supporters of the mechanical theory relied, can better be explained by the theory of self-regulation.

As examples of regulatory growth may be cited, the excessive formation of mechanical tissue in stems swayed by the wind compared with those held at rest by stakes; the growth of clasping organs when they support a weight compared with that of those affording no support; the great multiplication of mechanical tissue in roots, stems and petioles, when subjected to an artificial pull; and the failure to form their usual amount of supporting tissue by internodes encased in gypsum casts.

In the experiments with gypsum casts, the description of which constitutes the most of the original matter in the present paper, the plaster jackets used had a height of from three to five centimeters. The stems were encased and allowed to grow subsequently for several to many weeks. Examination of scores of these preparations on 25 species and a dozen genera showed that toward the middle of each segment in the cast there was a great lack of formation of mechanical tissue, the cells in this position remaining thin-walled, while corresponding elements in normal parts of the stem, and also those just within the limits of the cast, became thick-walled. A remarkable phenomenon was presented in the regions of the limits of the casts, where the mechanical tissue was abnormally strongly developed. This strong development extended into the cast for about a centimeter.

Here is apparently a good example of regulatory growth; for in the same stem, at the middle of the cast, where scarcely any external strain could have been felt, the mechanical tissue was deficient; while toward the limits of the cast, though the tissue was subjected to the same pressure, the thickening of cell-walls was excessive.

By regulatory growth also, stems whose development in one or two internodes had been checked by casts for several weeks, formed an abnormally large amount of supporting tissue after being released from the cast.

Although to term a certain kind of growth "regulatory" does not state the intimate causal relation, it does indicate that the growth is made in response to a stimulus, is an act due to irritability and not to merely mechanical force.

[This paper will be printed in the Botanical Gazette.]

THE WATERMELON DISEASE OF THE SOUTH. By Dr. ERWIN F. SMITH, Dept. of Agriculture, Washington, D. C.

[ABSTRACT.]

(1) A disease of the vine of hitherto unknown origin widely prevalent in the melon districts of the southeastern United States, and so destructive that growers in Georgia have settled down to the belief that it is impossible to raise melons on the same field two years in succession, or with profit oftener than once in five to seven years. In some districts of Georgia and South Carolina the disease has this year reduced the railway shipments one-half to one-third, and in the worst cases has taken the whole crop of individual cultivators.

(2) Large vines in full vigor wilt suddenly, in whole or part, without apparent cause. This wilt is followed in a few days by the death of the vine, but during this period there are no external indication of parasites, either above ground or below. The cortex is turgid, free from spotting, and normal in color, at the time the leaves begin to wilt.

(3) Constantly associated with the earliest stage of this disease is a white fungus apparently undescribed heretofore, and to which I have given the provisional name of *Fusarium niveum* until such time as its life history and place in the natural classification can be worked out. It occurs in the water-ducts of the stem, filling them more or less completely, and interfering with the movement of water from roots to foliage. In old vines this fungus was most abundant near the crown, but it was found in many parts of the root system, and in the vessels of the stem abundantly as far away from the roots as ½ to 1½ meters.

(4) This fungus gains entrance to the plant through the root system, and there are some indications that infection takes place principally during the first weeks after planting. Fifteen hundred hills of melons planted June 29 for experimental purposes were attacked and nearly all destroyed in four weeks time, the parts above ground remaining free from fungus attacks, and the Fusarium being found in the earliest stage of wilt only in the vessels of the roots.

(5) During the first week or two of the life of the seedling the fungus attacks all of the tissues, and the plants damp off in hot and wet weather in large numbers. Later the parenchyma becomes more resistant and the fungus betakes itself to the bundles, and especially to the ducts; but when the stem begins to shrivel it is again found invading the parenchyma.

(6) Conidia are produced abundantly within the vessels of the vine. These fall off when mature, float along in the vessels, germinate quickly, and form new plugs. Pure cultures have been made from these spores.

(7) Stem inoculations in South Carolina yielded uncertain results, owing to the prevalence of the disease and my inability to tell whether the experimental vines wilted from artificial or natural infection.

(8) Soil inoculations in a greenhouse at Washington are under way, but the results are not yet decisive. [Since this was written the chain of proof has been completed by obtaining numerous cases from three series of soil infections, made with pure cultures and controlled by many check plants.]

(9) The most badly attacked fields observed in South Carolina were those heavily fertilized with barnyard manure made from what is known locally as

'watermelon hay," *i. e.*, wild grass cut in autumn from melon fields, and including many blighted vines. This is composted and put back on the fields at time of planting. In my judgment, a modification in the method of manuring, a judicious rotation of crops, and the prompt destruction of diseased vines would do much to lessen the prevalence of this disease.

Paper accompanied by drawings, cultures of the fungus and microscopic slides, showing fungus in the bundles.

[This paper will be printed by United States Department of Agriculture.]

RELATION BETWEEN THE FUNCTIONS OF THE VEGETIVE AND REPRODUCTIVE LEAVES OF ONOCLEA. By Prof. GEO. F. ATKINSON, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THE complete differentiation between the vegetive and reproductive leaves of *Onoclea sensibilis* suggested that the so-called var. *obtusilobata*, which is an intermediate state, could be artificially induced by amputating the early vegetive leaves of this fern. The leaves were then cut from a patch of this fern on May 11th, June 9th, and July 12th, respectively. On the 12th of July a few leaves were seen which showed the transition stages. August 8th and 9th, the plants were gathered and every conceivable gradation between the fertile and sterile leaves was present, as illustrated in over thirty different plants. Some leaves of the fertile kind were expanded to a size equal to that of large sterile leaves, but usually the venation was coarser, and a few rudimentary indusia could usually be found on the basal pinnules of the lower pinnæ. Some leaves were found which it was impossible to properly correlate. The number and perfection of the sporangia as well as the indusia varied in accordance with the variation in the leaves. On those leaves or parts of leaves where but few or rudimentary sporangia were developed, there were frequently cases of apospory, rudimentary prothallia being also developed from the placental region.

ON THE SWARM SPORES OF PYTHIUM AND CERATIOMYXA. By Prof. GEO. F ATKINSON, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

RECENT study of a species of *Pythium*, probably the so-called *P. debaryanum*, Hesse, has served to show that either considerable confusion exists concerning our knowledge of the swarm spores, or that the genus is a very heterogeneous one.

The material for study was found in prothallia of ferns and in green-house cuttings of dicotyledons. The course of development both of the gonidial and oosporic stages agreed with those of this species quite well, except in the formation of the zoospores. The zoosporangia and primary division of the protoplasm into zoospores seemed to be normal. When the zoospores are mature, however,

they are ciliated at the two extremities of the slight reniform body, the ends of which are pointed. After swarming for awhile, plastic or amoeboid movements ensue without the loss of the cilia. Finally a constriction appears, and the swarm spore divides into two uniciliated swarm spores, which, after a swarming period, round off and germinate.

Pythium debaryanum, according to Hesse,[1] has uniciliated zoospores, the cilium being attached a little below the smaller end, and Sadebeck says that the zoospores of his *P. equiseti*[2] are exactly like those of *Cystosiphon*[3] *pythioides* Roze et Cornu (*Pythium*[4] *cystosiphon* Lind), which are biciliated, the form and position of the cilia being exactly like those of the *Pythium* which I have studied, though the swarm spores do not divide into uniciliated ones. Debary[5] considers *P. equiseti* Sadeb. to be identical with *P. debaryanum*, Hesse.

According to Pringsheim,[6] *Pythium entophytum* has uniciliated zoospores. The question arises as to whether or not these discrepancies may be harmonized by a critical study of the species of *Pythium*, and whether it is not true that all species possess at first biciliated zoospores which ultimately become uniciliated, or whether species vary, sometimes forming only biciliated zoospores, and in other cases these dividing into uniciliated ones. This character, together with others by which it differs from the *Saprolegniaceæ* and *Peronosporaceæ*, would seem to justify the erection of a new family for the species of *Pythium* as has been done by Schrœter.

In studying the germination of the spores of *Ceratiomyxa* a form was used which may be the type of a new species to be known as *C. plumosa*. Spores freshly matured and sown in pure water before drying germinated within two to six hours. The germination differs from that of any other genus of the *Myxomycetes*. Through a small opening in the wall of the spore a vermiform thread of protoplasm issues which possesses tortuous motions and slight amoeboid movement. This shortens and becomes amoebiform, short pseudopodia continuing to develop. Shortly by simultaneous parti-division four rounded lobes appear attached at the middle by a mass of protoplasm. These then farther divide into an eight lobed body, minute pseudopodia developing the mean time over the surfaces of all the lobes. A single long cilium is now developed from each lobe, and quite violent lashings follow, accompanied by the continued development of pseudopodia. The individual lobes separate frequently in pairs, which remain for a short time in communication, but eventually separate. Sometimes three to six may remain joined for several hours, assuming various shapes, but always showing the individual lobes and the long cilia. These frequently simulate the form of a star fish.

Ceratiomyxa, by the development of individual cells in the sporophore before the formation of the spores, differs from the true Myxomycetes, and approaches the simple cellular fungi. In the germination of the spores it approaches the genus *Pythium*, and this suggests a relationship with the *Phycomycetes*.

[1] Pythium debaryanum. Inaugural dissertation. Ein endophytischer Schmarotzer, Halle, 1874.

[2] Unters. u. Pythium equiseti, Beitrage z. Biologie d Pflanzen, Cohn's I. Hef 8, p. 121, 1875.

[3] Sur deux nouveaux types generiques pour les Familles des Saprolegniees et des Peronosporees. Ann. d. Sci. Nat. Bot. 5th ser. t. XI., p. 78, 1869.

[4] Syn. Saprolog. p. 50.

[5] Zur Kenntniss der Peronosporeen. Bot. Zeit. XXXIX., 8. 528, 1881.

[6] Jahrb. .f. Wis. Bot. I. p 289, 1859.

LOPHOPAPPUS, A NEW GENUS OF MUTISIACEOUS COMPOSITAE; AND FLUCKIGERIA, A NEW GENUS IN GESNERIACEÆ. H. H. RUSBY, M.D., 222 W. 132d St., New York City.

[ABSTRACT.]

GIVES general characters of groups to which the new genera belong, their positions in such groups, the occurrence of the plants on which the new genera are based, and the description of the latter.

[This paper will be printed in Bulletin Torrey Botanical Club.]

A REVISION OF THE GENUS SCOULERIA, ILLUSTRATED. By ELIZABETH G. BRITTON, Torrey Botanical Club, New York City.

[ABSTRACT.]

THE type of the genus, *Scouleria aquatica* will be described. *S. Nevii* and *S. Müller*i will be reduced to it. *S. marginata*, a new species, will be described and illustrated by plate and specimens, with slides for the microscope.

[This paper will be printed in the Bulletin of the Torrey Botanical Club.]

SOME NOTES ON THE GENUS EUCALYPTA. By ELIZABETH G. BRITTON, New York City.

[ABSTRACT.]

A COMPARISON between European and American Specimens of *Eucalypta ciliata*, with some notes on *E. longipes* and *E. Macounii*.

[This paper will be printed in the Bulletin of the Torrey Botanical Club.]

A HYBRID AMONG THE MOSSES. By ELIZABETH G. BRITTON, New York City, N. Y.

[ABSTRACT.]

THE first American record of a hybrid among mosses, showing both the normal fruit of one of the parent plants and the hybrid capsules, growing together from the same stem. Parents *Aphanorhegma serrata* ♀ × *Physcomitrium turbinatum* ♂ (?) distributed as *Schistidium serratum* in Drummond's Southern Mosses No. 20.

[This paper will be printed in the Bulletin of the Torrey Botanical Club.]

ON TORREYA AS A GENERIC NAME. By Dr. N. L. BRITTON, Columbia College, New York City.

[ABSTRACT.]

A REVIEW of the six genera of plants with which the name has been associated, and the history of the type species.

[This paper will be printed in the Bulletin of the Torrey Botanical Club.]

NOTES ON THE PRIMARY FOLIAGE AND THE LEAF-SCARS IN PINUS RIGIDA. By Dr. N. L. BRITTON, Columbia College, New York City.

[ABSTRACT.]

EXHIBITION of twigs and old bark of this pine, discussion of the foliar morphology, and suggestion of possible affinity with some extinct plants commonly grouped with Pteridophyta.

NOTES UPON CHALARA PARADOXA. By Prof. BYRON D. HALSTED, New Brunswick, N. J.

[ABSTRACT.]

THE fungus *Chalara paradoxa* (DeSeynes), Sacc., is recorded in Saccardo's Supplement to his Sylloge Fungorum. The writer studied it during the present year as growing upon pineapples. It furnishes the best material thus far met with for illustrating the internal abjunction of spores. When the time arrives for the production of these spores the tip of the hypha dissolves and the protoplasmic contents become divided serially into a row of hyaline cylindrical spores, which are pushed out of the tip of the spore-bearing hypha. While the process of spore-formation is at its height, the time for the deliverance of a spore may not exceed fifteen minutes.

There is a second form of spore much larger than those above described, that forms in the ordinary way, and not separating readily, produces long necklace chains. There is a third form of spore midway between the two sorts mentioned in that it is produced by internal abjunction, is not hyaline, but brown and oval. This is likely a variation due to conditions under which the spores are produced. There are also spores produced within the substance of the host (pineapple flesh) that are still different.

NOTES UPON A ROOT ROT OF BEETS. By Prof. BYRON D. HALSTED, New Brunswick, N. J.

[ABSTRACT.]

DURING the present year a serious fungus decay was found upon the roots of field and garden beets. It seems to be an undescribed species of the genus Phyllosticta. The leading points in the present paper are: the rapid and profuse development of the Pycnidia of this fungus upon the cut surface of the affected parts of the beets; the complete separation of the Pycnidia by the intervention of a layer of thin cloth laid upon the freshly cut surface, and the confirmation of previous statements regarding the non-sexual origin of the Pycnidia.

[This paper will be printed in the Bulletin of the Torrey Botanical Club.]

SPECIES OF TAPHRINA PARASITIC ON POPULUS. By Mrs. F. W. PATTERSON 29 Hammond St., Cambridge, Mass.

[ABSTRACT.]

AMERICAN mycologists formerly referred to *Taphrina aurea* specimens occurring on ovaries of *Populus tremuloides* and other hosts. It has been shown,

however, that the name *T. aurea* belongs only to the form on leaves, which has not heretofore been known in America. The form on ovaries was then supposed to be identical with Johanson's *T. rhizophora*, but from this it now proves to be quite distinct and easily recognized by size of asci as belonging to *T. Johansonii*, Sadebeck. A form differing but slightly from *T. aurea* has now been found also in Iowa, parasitic on leaves of several species of *Populus* planted from Europe.

EVIDENCE AS TO THE FORMER EXISTENCE OF LARGE TREES ON NANTUCKET ISLAND. By BURT G. WILDER, Ithaca, N. Y.

IN his Report on the Geology of Nantucket (Bulletin of the United States Geological Survey, No. 53, 1889, Fig. 9), Prof. N. S. Shaler represents a section of a submerged swamp on the north shore of Nantucket with tree-stumps, one of which he says is 10 inches (25 cm.) in diameter. On p. 52 he writes: "I am inclined to believe that when this island was first settled the greater part of its surface, at least that portion of the area north of the southern plains, was covered with a forest growth which afforded some architectural timber." But he does not mention having personally observed any large tree remains in the interior of the island, and refers to the tradition that the former oaks and pines were "sufficiently large to afford ship timber as well as material for edifices" as "unsupported by any trustworthy record." Hence some positive evidence is desirable.

Several years ago I was told by Mr. Harry Dunham that in cutting peat at Polpis he often encountered fragments of large trees. On the 15th of August, in company with Professors Harrison Allen, M.D., of the University of Pennsylvania, and W. K. Hatt of Purdue University, Indiana, I visited an old peat bog at Polpis, at Hughes' Neck, west of the main road, not far from what is reputed to be the oldest house on the island. The proprietor, Mr. Charles Swain, kindly led us to a stump standing undisturbed in a dense thicket on top of a bog where the soft peat is still a meter thick. The crown of this stump measures in diameter about 50 cm. (20 in.), and is thus twice the size of that mentioned by Professor Shaler. Photographs were taken of it and of a neighboring bog, more recently worked and covered with water, where are visible more than twenty uprooted stumps of various sizes.[1]

PRODUCTS OF METAMORPHOSIS OF MONSTROSITIES. By ALBERT MANN, Ph. D., 483 First St., Brooklyn, N. Y.

[This paper will be printed in the Botanical Gazette.]

THE GROWTH OF FOREST TREES ILLUSTRATED FROM MARKED CORNERS, 107 YEARS OLD. By Major JED. HOTCHKISS, Staunton, Va.

[1] A week later the stump was extracted and found to be oak in a good state of preservation. Sections will be deposited in the U. S. National Museum, in the Museum of Comp. Zoölogy, in the Museum of Cornell University, and in the Nantucket Athenæum.

THE COMMITTEE ON BIBLIOGRAPHY AND TYPOGRAPHY PRESENTED THE FOLLOWING REPORT: —

THE Committee on Bibliography and Typography appointed by the Madison Botanical Congress was directed to report to Section G of the American Association for the Advancement of Science. This section therefore is asked to receive the following report and take such action thereupon as seems wise: —

The committee report that progress has been made during the past year in carrying out the suggestions made to the Madison Botanical Congress.[1] The first recommendation thereto made, viz., "that there should be published . . . . a catalogue of papers [relating to American botany] by authors," has been undertaken, and so far as it has gone has been successfully accomplished by the co-operation of a number of botanists with the editors of the *Bulletin* of the Torrey Botanical Club and the Cambridge Botanical Supply Co. This index, printed first in the *Bulletin*, is reprinted upon standard cards by the Cambridge Botanical Supply Co., so that any number of copies can be had and arranged by subjects or by journals as desired. Every effort will be made by those charged with the preparation of this index and its first publication to make it complete, and to have it conform exactly to the rules of citation prepared by this committee. The work of publication upon cards, however, is not adequately supported. The committee sincerely hope that this form of publication will not have to be given up, and they therefore urge that those interested testify their interest by sending their subscriptions to the Cambridge Botanical Supply Co., Cambridge, Mass.

The committee also announce that the *Botanical Gazette*, in connection with the Cambridge Botanical Supply Co., is ready to undertake the publication of the supplementary list of journals referred to in section 1, *b*. of the committee's report[2] to the Congress which appointed it. The publication of these lists of journals upon cards will be begun as soon as subscribers sufficient to defray the expense of printing the cards can be secured. In the same way the *Bulletin* of the Torrey Botanical Club will undertake the publication of the list of authors referred to in the committee's report under *l. c.* If the number of subscribers to the index of papers above mentioned as in course of publication can be immediately increased, these author and journal cards will, for the present year, be sent free to subscribers.

The committee again call attention to the index of new genera and species of plants now being issued on cards by Miss Josephine A. Clark, of Washington, D. C., and commend this to the support of botanists. Regarding this private publication, they beg to suggest (1) That there be added to these cards such marks as will serve to identify the series when distributed in other indexes; (2) That in the interest of completeness *all* new names relating to North American plants be included.

A year's experience in the working of the rules for citations approved by the Madison Congress has not shown the necessity or desirability of any changes. To those rules, however, the committee desire to add the following amplification:

[1] Proceedings Madison Botanical Congress, 45. June, 1894.

[2] Loc. cit.

In *f*, p. 46, l. c., before the last sentence insert: In case the original paging is unknown an em dash should occupy its place, the reprint paging being given in accordance with the foregoing rule.

The committee also recommend the adoption of the two following paragraphs as addenda:

j. If it is considered desirable to give other data than series number (if any), volume number, page, and date, these should be added in brackets after the date. But useless or unnecessary data should be avoided.

k. Citations of reviews, abstracts, and all such secondary references, should be enclosed in parentheses.

Since uniformity is the chief object in the adoption of the rules for citation by the Congress, the committee call attention to the necessity of an exact following of these rules by as many writers and publishers as can be induced to give adhesion to them. To facilitate this, we recommend that the editors of the *Bulletin* of the Torrey Botanical Club, the *Botanical Gazette*, *Erythea*, and the *American Naturalist* be requested to publish these rules, and examples of as great a variety of citations as practicable. The Committee also desire to issue these on tag-board sheets, in a form which can be readily distributed and preserved for convenient reference. To enable the Committee to do this, and to disseminate information upon these points, we recommend that the Council of the A. A. A. S. be requested to make a grant of $25 to cover the necessary expenses which may be incurred. [This grant was made by the Council.]

The report was accepted and adopted, and the Committee continued.

THE COMMITTEE ON THE NOMENCLATURE OF PLANT DISEASES PRESENTED THE FOLLOWING REPORT.

THE Committee upon the Nomenclature of Plant Diseases appointed by the Madison Botanical Congress, by vote of that body begs to make the following report: —

The Committee finds itself with a somewhat difficult task upon its hands. Names of fungous diseases that are now in general use it will be difficult if not impossible to uproot and set aside. Thus the black rot of the grape and black knot of plum and cherry are well known, distinctive, and fixed. In an ideal nomenclatural system there would be distinctive common names for the various groups. This in a measure has been accomplished, for we have downy mildews for Peronosporeæ, rusts for Uredineæ, and smuts for Ustilagineæ. There is a vast number of species of the large genera like Septoria, Phyllosticta, Cercospora, Ramularia, etc., that are not easily given general names. Thus a Septoria or Phyllosticta may produce a definite spot upon the leaf or affect the whole area, and the term "leaf spot" is inappropriate. It is possible, for example, for blights (pear), rots (hyacinth), wilts (melon), tuberculosis (olive), and other diseases to be produced by bacteria. It is suggested that when possible the term bacteriosis be used for such cases. This can be done when a mycologist has the opportunity to set forth the disease before the world, and antedate any name or names, for there may be many, that arise among the people.

Anthracnose is a name that is used so generally that it has very little significance. It should, like many others, be restricted.

Without further argument, the principal points which the Committee would respectfully present for your consideration are as follows:—

(1) When a good name has become firmly established, no effort should now be made to change it, except when it is manifestly inappropriate, as the so-called "strawberry rust" and "celery rust."

(2) There should be terms to distinguish between the parasite and the disease it produces. It is awkward to say "this disease is *rust*, and it is produced by a *rust*." An improvement upon this would be to state that this disease is uredinosis, and is produced by a rust, giving the botanical name of the rust, or even the genus when possible.

(3) The diseases need to have, for popular use, English, or at least Anglicised names, and these may well be derived from those already in use.

(4) Names should be as far as possible descriptive, and indicate the plant attacked; therefore more than one word will usually be required, as "peach leaf-curl," the last two words being hyphened. There will be many cases where the name of the host can be coupled with the genus of the parasite, thus giving a substantial compound name, as potato-macrosporium or bean-colletotrichum.

(5) After the pathology of plant diseases is understood much better than now, a scientific classification of them can be made, and appropriate names given to each; at present only an artificial system can be hoped for.

A tentative classification and nomenclature may be made in various ways, as, e. g.:

(*a*) from the group names of the parasites as the

Uredineæ	producing	uredinosis
Bacteria	"	bacteriosis
Ustilagineæ	"	ustilaginosis

(*b*) from the gross effect upon the host as rot, scab, spot, blight, rust, smut, club-root, black-knot, mold, gall, damping off, etc., from which Latinized names might be constructed, and

(*c*) from the general cause of the disease; (1) unfavorable habitat, (2) unfavorable atmospheric conditions, (3) mechanical injuries, (4) parasitism, (5) teratogeny.

(6) From what has been presented above, it is clear that the results obtained by the Committee are far from final, and therefore it is suggested that the work be continued, and that it be along the following among other lines:

(*a*) Collate and tabulate the common names of plant diseases now in use.

(*b*) Construct a working scheme in which every plant disease is assigned a place with a distinctive (scientific) name followed by an English name, the last to be, when possible, the one already in use.

(*c*) It is recommended that the parasite should be distinguished from the disease in all cases.

(*d*) It goes without saying that mycologists are urged to apply names to plant diseases instead of leaving the matter of a choice to a popular verdict.

Byron D. Halsted,
B. T. Galloway,
Geo. F. Atkinson,
Charles E. Bessey,
For the Committee.

Report received, adopted, and the Committee continued.

Association Table at Woods Holl Laboratory.

In joint session of Sections F and G, the following resolutions of the Committee of the A. A. A. S. on a table at the Marine Biological Laboratory at Woods Holl, Mass., were offered by Dr. S. H. Gage for adoption by the Sections: —

The Sections of Zoology and Botany (F and G) request that the Association continue its subscription of $100 for an investigators' table at the Marine Biological Laboratory at Woods Holl, Mass.

The two Sections in joint session also make the following suggestions for the award and government of the table subscribed for by the Association.

1. That the table shall be known as the A. A. A. S. table.

2. That the award of this table shall be entrusted to a committee of five, consisting of the vice president and secretary elect of each Section (F and G), and of the director of the Marine Biological Laboratory (at present C. O. Whitman).

3. Any fellow or member of the A. A. A. S. shall be eligible for appointment to the table. (An applicant for membership in the Association will be considered as a member, and therefore eligible.)

4. Applications for the table are to be made to the permanent secretary, who shall forward them to the senior vice-president of Sections F and G, seniority being determined as in § 11 of the Constitution, *i. e.*, according to continuous membership.

5. That the holders of the Association's table are expected to give proper credit for the use of the table in all published results of investigations carried on at the table.

[The grant for the table was made by the Council.]

SECTION H.

ANTHROPOLOGY.

OFFICERS OF SECTION H.

Vice President.

FRANZ BOAS, Washington, D. C.

Secretary.

ALEX. F. CHAMBERLAIN, Worcester, Mass.

Councillor.

W. J. MCGEE.

Sectional Committee.

FRANZ BOAS, *Vice President*, 1894, A. F. CHAMBERLAIN, *Secretary*, 1894, J. OWEN DORSEY, *Vice President*, 1893, W. K. MOOREHEAD, *Secretary*, 1893, W. M. BEAUCHAMP, STEWART CULIN, M. H. SAVILLE.

Member of Nominating Committee.

MATILDA C. STEVENSON.

Committee to Nominate Officers of Section.

FRANZ BOAS, *Vice President*, A. F. CHAMBERLAIN, *Secretary*, ANITA NEWCOMB MCGEE, PAUL CARUS, F. H. CUSHING.

Press Secretary.

STEWART CULIN.

ADDRESS

BY

FRANZ BOAS,

VICE PRESIDENT, SECTION H.

HUMAN FACULTY AS DETERMINED BY RACE.

PROUD of his wonderful achievements, civilized man looks down upon the humbler members of mankind. He has conquered the forces of nature and compelled them to serve him. He has transformed inhospitable forests into fertile fields. The mountain fastnesses are yielding their treasures to his demands. The fierce animals which are obstructing his progress are being exterminated, while others which are useful to him are made to increase a thousand fold. The waves of the ocean carry him from land to land and towering mountain ranges set him no bounds. His genius has moulded inert matter into powerful machines which wait a touch of his hand to serve his manifold demands.

What wonder when he pities a people that has not succeeded in subduing nature; who labor to eke a meagre existence out of the products of the wilderness; who hear with trembling the roar of the wild animals and see the products of their toils destroyed by them; who remain restricted by ocean, river or mountains; who strive to obtain the necessities of life with the help of few and simple instruments.

Such is the contrast that presents itself to the observer. What wonder if civilized man considers himself a being of higher order as compared to primitive man; if it is claimed that the white race represents a higher type than all others.

When we analyze this assumption, it will soon be found that the superiority of the civilization of the white race alone is not a sufficient basis for this inference. As the civilization is higher, we assume that the aptitude for civilization is also higher; and as the aptitude for civilization presumably depends upon the perfection of the mechanism of body and mind, the inference is drawn that the white race represents the highest type of perfection. In this conclusion, which is reached through a comparison of the social status of civilized man and of primitive man, the achievement and the aptitude for an achievement have been confounded. Furthermore, as the white race is the civilized race, every deviation from the white type is considered a characteristic feature of a lower type. That these two errors underlie our judgments of races can be easily shown by the fact that, other conditions being equal, a race is always described as the lower the more fundamentally it differs from the white race. This becomes clearest by the tendency on the part of many anthropologists to look for anatomical peculiarities of primitive man which would characterize him as a being of lower order, and also by the endeavors of recent writers to prove that there exist hardly any anatomical features of the so-called lowest races which would stamp them as lower types of organisms. Both these facts show that the idea dwells in the minds of investigators that we should expect to find in the white race the highest type of man.

In judging social distinctions the same error is frequently committed. As the mental development of the white race is the highest, it is also supposed to have the highest aptitude in this direction, and therefore its mind is supposed to have the most subtle organization. As the ultimate psychical causes are not so apparent as anatomical characters, the judgment of the mental status of a people is generally guided by the difference between its social status and our own; the greater the difference between their intellectual, emotional and moral processes and those which are found in our civilization the harsher the judgment on the people. It is only when a Tacitus finds the virtues of past stages of the culture of his own people among foreign tribes, that their example is held up to the gaze of his fellow-citizens, who probably had a pitying smile for the dreamer who clung to the ideas of a time which they had left far behind.

It might be objected that although achievement is not necessarily

a measure of aptitude, it seems admissible to judge the one by the other. Have not most races had the same chances for development? Why, then, did the white race alone develop a civilization which is sweeping the whole world and compared to which all other civilizations appear as feeble beginnings cut short in early childhood, or arrested and petrified in an early stage of development? Is it not, to say the least, probable that the race which attained the highest stage of civilization was the most gifted one, and that those races which remained at the bottom of the scale were not capable of rising to higher levels?

It seems desirable to enter into these questions somewhat fully. Let our mind go back a few thousand years until it reaches the time when the civilizations of eastern and of western Asia were in their infancy. As time passed on, these civilizations were transferred from one people to another, some of those who had represented the highest type of culture sinking back into obscurity, while others took their places. During the dawn of history we see civilization clinging to certain districts, in which it is taken up now by one people, now by the other. In the numerous conflicts of these times the more civilized people were often vanquished. The conqueror, however, learned the arts of life from the conquered and carried on the work of civilization. Thus the centres of civilization were shifting to and fro over a limited area and progress was slow and often interrupted. At the same period the ancestors of the races, who are now among the most highly civilized, were in no way superior to primitive man as we find him now in regions that have not come into contact with modern civilization.

Was the culture attained by the ancient civilized people of such character as to allow us to claim for them a genius superior to that of any other race? First of all, we must bear in mind that none of these civilizations was the product of the genius of a single people. Ideas and inventions were carried from one to the other; and, although intercommunication was slow, each people which participated in the ancient civilization added to the culture of the others. Proofs without number have been forthcoming which show that ideas have been disseminated as long as people have come into contact with each other and that neither race nor language nor distance limits their diffusion. As all have worked together in the development of the ancient civilizations, we must bow to the genius of all, whatever race they may represent: Hamitic, Semitic, Aryan or Mongol.

We may now ask, Did no other races develop a culture of equal value? It would seem that the civilizations of ancient Peru and of Central America may well be compared with the ancient civilization of the Old World. In both we find a high stage of political organization; we find division of labor and an elaborate ecclesiastical organization. Great architectural works were undertaken requiring the coöperation of many individuals. Animals and plants were domesticated and the art of writing had been invented. The inventions and knowledge of the peoples of the Old World seem to have been somewhat more numerous and extended than those of the races of the New World, but there can be no doubt that the general status of their culture was nearly equally high. This will suffice for our consideration and I will not enter upon the fact that a greater variety of peoples had contributed to the progress of civilization in the Old World, and that nature had endowed their homes more abundantly with useful animals and plants than the homes of the peoples of the New World.

What then is the difference between the civilization of the Old World and that of the New World? It is only a difference in time. The one reached a certain stage three thousand or four thousand years sooner than the other. This difference in period does not justify us to assume that the race which developed more slowly was less gifted. Certainly the difference of a few thousand years is insignificant as compared to the age of the human race. The time required to develop the existing races is entirely a matter of conjecture, but we may be sure that it was long. We also know that man existed in the eastern and western hemispheres at a time which can be measured by geological standards only; and, if we assume arbitrarily no more than 20,000 years as the age of man, what would it mean that one group of mankind reached the same stage at the age of 20,000 years which was reached by the other at the age of 24,000 years? Would not the life history of the people and the vicissitudes of its history be fully sufficient to explain a delay of this character, without necessitating us to assume a difference in their aptitude to social development?

When admiring the high achievements of the white race we also ought to bear in mind that civilization originated among few of its members and by the help of other races, and that there is no evidence that the cognate tribes which have all developed under the influence of this ancient civilization would not, without its help,

have required a much longer time to reach the high level which they now occupy.

But why did these tribes so easily assimilate the culture that was offered them, while at present we see primitive people dwindle away and become degraded before the approach of civilization, instead of being elevated by it? Is not this a proof of a higher organization of the inhabitants of Europe? I believe the reasons for this fact are not far to seek and do not necessarily lie in a greater ability of the races of Europe and Asia. First of all, these people were alike in appearance to civilized man of their times. Therefore the fundamental difficulty for the rise of primitive people, namely, that an individual which has risen to the level of the higher civilization is still looked upon as belonging to an inferior race, did not prevail. Thus it was possible that, in the colonies of ancient times, society could grow by accretion from among the more primitive people. Furthermore, the devastating influences of diseases which nowadays begin to ravage the inhabitants of territories newly opened to the whites were not so strong on account of the permanent contiguity of the people of the Old World who were always in contact with each other and therefore subject to the same influences. The invasion of America and Polynesia, on the other hand, was accompanied by the introduction of new diseases among the natives of these countries. The suffering and devastation wrought by epidemics which followed the discovery are too well known to be described in full.

In addition to this it may be said that the contrast between the culture represented by the modern white and that of primitive man is far more fundamental than that between the ancients and the people with whom they come in contact. Particularly, the methods of manufacture have developed so enormously that the industries of the primitive people of our times are exterminated by the cheapness and large quantity of the products imported by the white trader; because primitive man is unable to compete with the power of production of the machines of the whites, while in olden times the superior hand product rivalled with a hand product of a lower type. It must also be considered that in several regions, particularly in America and in parts of Siberia, the primitive tribes are swamped by the numbers of the immigrating race which is crowding them so rapidly out of their old haunts that no time for gradual assimilation is given. In olden times there was certainly no

such immense inequality in numbers, as we observe in many regions nowadays.

We conclude, therefore, that the conditions for assimilation in ancient Europe were much more favorable than in those countries, where in our times primitive people come into contact with civilization. Therefore we do not need to assume that the ancient Europeans were more gifted than other races which have not become exposed to the influences of civilization until recent times.

This conclusion may be corroborated by other facts. In the middle ages, the civilization of the Arabs had reached a stage which was undoubtedly superior to that of many European nations of that period. Both civilizations had sprung largely from the same sources and must be considered branches of one tree. The Arabs who were the carriers of civilization were by no means members of the same race as the Europeans, but nobody will dispute their high merits. It is of interest to see in what manner they influenced the negro races of the Soudan. At an early time, principally between the second half of the eighth century and the eleventh century of our era, the Soudan was invaded by Hamitic tribes and Mohammedanism was spreading rapidly through the Sahara and the western Soudan. We see that, since that time, large empires were formed and disappeared again in struggles with neighboring states and that a relatively high degree of culture has been attained. The invaders intermarried with the natives, and the mixed races, some of which are almost purely negro, have risen high above the level of other African negroes. The history of Bornu is perhaps one of the best examples of this kind. Barth and Nachtigal have made us acquainted with the history of this state, which has played a most important part in the history of north Africa.

Why, then, have the Mohammedans been able to civilize these tribes and to raise them to nearly the same standard which they had attained, while the whites have not been capable of influencing the negro in Africa to any considerable extent? Evidently on account of the different method of introduction of culture. While the Mohammedans influence the people in the same manner in which the ancients civilized the tribes of Europe, the whites send only the products of their manufactures and a few of their representatives into the negro country. A real amalgamation between the higher types of the whites and the negroes has never taken

place. The amalgamation of the negroes by the Mohammedans is facilitated particularly by the institution of polygamy, the conquerors taking native wives and raising their children as members of their own family.

The spread of the Chinese civilization in eastern Asia may be likened to that of the ancient civilization in Europe. Colonization and amalgamation of kindred tribes and, eventually, extermination of rebellious subjects with subsequent colonization, have led to a remarkable uniformity of culture over a large area.

When, finally, we consider the inferior position held by the negro race of the United States, who are in the closest contact with modern civilization, we must not forget that the old race-feeling of the inferiority of the colored race is as potent as ever and is a formidable obstacle to its advance and progress, notwithstanding that schools and universities are open to them. We might rather wonder how much has been accomplished in a short period against heavy odds. It is hardly possible to say what would become of the negro if he were able to live with the whites on absolutely equal terms.

Our conclusion drawn from the foregoing considerations is the following: Several races have developed a civilization of a type similar to the one from which our own had its origin. A number of favorable conditions facilitated the rapid spread of this civilization in Europe. Among these, common physical appearance, contiguity of habitat and moderate difference in the modes of manufacture were the most potent. When, later on, civilization began to spread over other continents the races with which modern civilization came into contact were not equally favorably situated. Striking differences of racial types, the preceding isolation which caused devastating epidemics in the newly discovered countries and the greater advance in civilization made assimilation much more difficult. The rapid dissemination of Europeans over the whole world cut short all promising beginnings which had arisen in various regions. Thus no race except that of eastern Asia was given a chance to develop an independent civilization. The spread of the European race cut short the growth of the existing independent germs without regard to the mental aptitude of the people among whom it was developing. On the other hand, we have seen that no great weight can be attributed to the earlier rise of civilization in the Old World which is satisfactorily explained

as a chance. In short, historical events appear to have been much more potent in leading races to civilization than their faculty, and it follows that achievements of races do not warrant us to assume that one race is more highly gifted than the other.

We will next compare the physical and psychical characteristics of the various races with a view to the question of their mental ability.

There is no doubt that great differences exist in the physical characteristics of the races of man. But the question is not if differences exist, but if any one race is anatomically considered superior to others. It is clear that our answer cannot be based upon vague descriptions of travellers who remark upon the enormous digestive organs of primitive man, or on his small size, or on the lack of development of his limbs, or even upon his resemblance to apes, but upon serious studies of anatomical characteristics. A number of these differences are sufficiently fundamental to distinguish certain races clearly from others, although we must bear in mind that innumerable transitions exist between the races of man. The color of the skin, the form of the hair and the configuration of the lips and nose distinguish the African negro clearly from most other races. Nevertheless, it would be easy to find among members of the American race, for instance, lips and nose which might be mistaken for those of a negro. The same may be said of color, while no negro hair will be found among American aborigines. When studying any single anatomical characteristics of races, we find the same phenomenon which was observed in the cases here quoted: the variations inside any single race are such that they overlap the variations in another race so that a number of characteristics may be common to individuals of both races. Still, the single feature does not characterize the race and the differences are sufficiently numerous to permit a satisfactory definition of the characters of races.

The overlapping of variations is significant in so far as it shows that the existing differences are not fundamental. I will describe these phenomena somewhat more fully and enumerate at the same time a number of variations between races. In treating first the anthropometric characteristics I must call to mind the important fact, which is frequently overlooked in comparisons of races, that the proportions of the body show certain correlations which must be taken into consideration. The most obvious of these is the

correlation between stature and sizes of parts of the body. For this reason tribes of different stature cannot be compared without a proper reduction of the observed figures. In our comparison it will be well to pay particular attention to those races which we are inclined to consider the lowest; to wit, the negroid races and the oldest prehistoric races.

The proportions of the body as found among various races show very slight differences only. We may say that the trunks of the Mongoloid races as compared to their statures are longer than those of Europeans whose trunks in turn are longer than those of the negroes; that the lower limbs of the last-named race are longer than those of the white and Mongoloid races, and that the same is true in regard to the upper limbs. The head of the Mongoloid race is highest when compared to the stature; that of the negro is smallest. All these differences are slight and not in such a direction as to make one race more ape-like than the other. On the contrary, we find that the characteristic differences between man and ape are often more pronounced in the negro race than in the white race, and we may say with Ranke that many proportions of the lower races are to a higher degree human than those of the white.

In judging the value of these differences we must remember that the proportions of the body do not depend entirely upon descent, but just as much upon mode of life. Fritsch was the first to make it clear that between primitive man and civilized man differences are found which are quite in accord with the differences between wild animals and domesticated animals, and we all know how far-reaching the influence of domestication may become. He found that the skeletons of primitive races remain lighter while the bones are thinner and denser than those of civilized man. The secondary sexual characters are not clearly marked and effects of malnutrition or irregular nutrition are always present. The necessity of physical effort which applies to all the muscles of the body causes a different development from that observed in civilized man, in whom muscular effort is slighter or more specialized. These conclusions are borne out by the striking differences in the proportions of the body which develop among different occupations inside the same population.

The best authenticated fact, because it is based on the greatest number of observations, is the difference in type between sailors

and soldiers who were measured during the war of the Rebellion. It was found that sailors had legs as long as those of the negroes and correspondingly a shorter trunk, while their arms were equally long as those of the soldiers of the army. We may also call to mind the investigations carried on in the gymnasia of our colleges which show that a series of measurements which depend largely upon the functions of groups of muscles change very rapidly under the influence of practice. It will be acknowledged at once that differences in the use of muscles during childhood and continued in later life must result in differences of structure. Such differences must, therefore, not be considered racial but cultural features. The differences which cannot be explained by functional causes are few in number and they are not of such a character as to stamp one race as lower than the other.

We will next consider a number of formations which have often been described as characterizing lower races or as theromorphisms. One of these is a variation in the form of the temporal bone which, in man, is ordinarily separated from the frontal bone by the sphenoid and parietal bones. It has been found that in some individuals the temporal bone encroaches upon the sphenoid and parietal and comes into contact with the frontal bone. This formation is the prevalent one among the apes. It has been proved that this variation is found among all races but with unequal frequency, and that it is probably connected with disturbances in the formation of the temporal region which depend upon malnutrition in early infancy. We must therefore not wonder that the phenomenon is found more frequently among primitive people than among civilized people.

The peculiar formation of the tibia known as platycnemism, which has been observed on skeletons of the oldest remains of man in Europe and which was considered a proof of his lower stage of development, and the peculiar formation of the articular surfaces of tibia and femur, have been recognized as purely functional and as occurring among all races of the present times.

Certain other variations which were at one time considered as characteristics of races are also found to occur all over the world. Such are the *Os Incæ* which occurs among all races but most frequently among the Peruvians and the inhabitants of the ancient pueblos; the smallness of the nasal bones and their synos osis with the maxilla; the so-called prenasal fossæ; the variations in the

arrangement of arteries and of muscles. All these variable features are found to vary among all races, but the degree of variability is not everywhere the same. Presumably such variations may be considered human characteristics which have not yet had time to become stable and which in this sense may be considered as still in process of evolution. If this interpretation be correct, it might seem that we can consider those races in which the various features are more stable as those which are more highly organized.

This would refer, however, only to such features as are not caused by the influence of environment. But even this conclusion is subject to an important restriction. Numerous primitive tribes are very small in numbers or have had for long periods, during which they increased in numbers, little intercourse with foreign people. If, in such a group, any of the original families showed a certain peculiarity, it must now be found more frequently than in other tribes. A case of this kind is the frequency of supernumerary vertebræ among the Indians of Vancouver Island, and probably also the frequency of the *torus palatinus* among the Lapps. It may be left an open question, if the frequent occurrence of the *Os Incæ* among the Pueblo Indians may be explained by the same consideration. Therefore, it may be that the greater variability of certain races, in regard to these phenomena, is not an expression of a lower degree of development of the whole group, but of the presence of a great number of members of a family which possessed the peculiar character. That is to say, in order to admit the conclusion that greater variability means lower stage of development, it would be necessary first to prove that the variations appear spontaneously among any number of the group and do not belong to certain families in which the feature is hereditary.

While the consideration of the characters treated heretofore has not given any conclusive evidence of the superiority of certain races, the study of the form and size of the head seems to promise better results. We find that the face of the negro as compared to the skull is larger than that of the American, whose face is in turn larger than that of the white. The lower portion of the face assumes larger dimensions. The alveolar arch is pushed forward and thus gains an appearance which reminds us of the higher apes. There is no denying that this feature is a most constant character of the black races and that it represents a type slightly nearer the animal than the European type. The same may be said of the

broadness and flatness of the nose of the negro and of the Mongol; but here again we must call to mind that prognathism and low, broad noses are not entirely absent among the white races, although the more strongly developed forms which are found among the negroes do not occur. The variations belonging to both races overlap. We find here at least a few indications which tend to show that the white race differs more from the higher apes than the negro. But does this anatomical difference prove that their mental capacity is lower than that of the white? The probability that this may be the case is suggested by the anatomical facts, but they by themselves are no proof that such is the case. I shall revert to this subject later on.

It has been stated that the individuals of certain races are arrested in their development earlier than others and that the latter races must therefore be considered as more highly developed. Among these phenomena I will mention the fact that the noses of children of various races are more alike than those of adults. The nose of the Mongols does not change so much during adolescence as that of the whites. According to Quatrefages the basin of the negro does not differ so much from the fœtal forms as that of other races and resembles at the same time more that of higher apes than the basins of other races. On the other hand, the face of the negro child is less prognathous than that of the adult. In this case we find that the more energetic development tends to produce a type which is apparently lower than that of the white. We may even go a step farther and say that the ontogenetic development of the higher apes and of man is such that the young forms are more alike than the old ones. While in man the face develops moderately only, it grows considerably among the apes. The earlier arrest in this case is therefore an indication of higher type. Thus it will be seen that it is not the earlier arrest alone which determines the place of a race, but the direction of this development. For this reason we cannot assume that the earlier arrest of development of that portion of the face situated between the eyes, as is observed in the Mongol race, is an indication of a lower type, while the marked increase of breadth and elevation of nose, as found among the whites indicates a higher type.

In a general review of these phenomena we find that the peculiarities of the various races develop in such a manner that some remain in one respect on earlier stages than others, while other

features develop more strongly. Among instances of such development carried on to a higher degree may be mentioned the large size of the frontal sinuses among the Melanesians, the prognathism of the Negroes, the greater length of the limbs of the same race, the high and narrow nose of the whites. In judging the value of these facts we must also not forget that the female sex is in all the proportions and forms of its body more like the child than the male, and that the most specialized types appear among the male sex. But who would explain this earlier arrest of development of women as mark of a lower type?

In comparing human races in regard to the periods over which the development of certain parts of the bodies extend, we must always consider the functions of the organs in question. If we could prove that the brain of certain races ceases to develop at an earlier period than that of others, the inference of the inferiority of race would seem highly probable. At the present time no satisfactory basis for such comparisons exists. Growth during adolescence is always small, and extensive and accurate series of observations are required in order to establish any characteristic differences between races. It has been shown that among the white race growth of the whole body continues until after the thirty-fifth year. The same phenomenon has been observed among the negroes, while the Indians appear to have reached their highest stature before the thirtieth year. The growth of the head of Indians and whites seems to extend over an approximately equal period. It would be of great interest, if we could ascertain the growth of the head of other races with accuracy. Since it has been proved that the most gifted students of our colleges show a longer period of growth than those who form the average class, the period of head-growth has become of great importance in connection with our inquiry.

Unfortunately, data are lacking entirely at least for a comparison between the white race and those races which are considered the lowest. As we know that the laws of the general growth of the body of the Indian and of the white differ considerably, the inference is justified that such differences may be found in the growth of certain organs and that they will prevail among different races. It is true that in such comparisons mortality, nutrition, occupation, play an important part; but, nevertheless, racial differences may be expected to exist. In fact, the similarity of children of various

races and the dissimilarity of the adult make it certain that they will be found and we anticipate that they will give us a better idea of the relation of the races than comparison of the adult stage alone can do.

We will now turn to the important subject of the size of the brain, which seems to be the one anatomical feature which bears directly upon the question at issue. It would seem that the greater the central nervous system, the higher the faculty of the race and the greater its aptitude to mental achievements. Let us review the known facts. Two methods are open for ascertaining the size of the central nervous system: the determination of the weight of the brain and that of the capacity of the cranial cavity. The first of these methods is the one which promises the most accurate results. Naturally, the number of Europeans whose brain-weights have been taken is much larger than that of individuals of other races. There are, however, sufficient data available to establish beyond a doubt the fact that the brain-weight of the whites is larger than that of most other races, particularly larger than that of the negroes. That of the white male is about 1370 grammes. The investigations of cranial capacities are quite in accord with these results. According to Topinard, the capacity of the skull of males of the neolithic period of Europe is about 1560 cc.; that of modern Europeans is the same; of the Mongoloid race 1510 cc.; of African negroes 1405 cc., and of negroes of the Pacific ocean 1460 cc. Here we have, therefore, a decided difference in favor of the white race. These differences cannot be explained as the effect of difference in stature, the negroes being at least as tall as the Europeans.

In interpreting these facts we must ask, Does the increase in the size of the brain prove an increase in faculty? This would seem highly probable and facts may be adduced which speak in favor of this assumption. First among these is the increase of the relative size of the brain among higher animals, thence to man. Furthermore Manouvrier has measured the capacity of the skulls of thirty-two eminent men. He found that they averaged 1663 cc. as compared to 1560 cc. general average. On the other hand he found that the cranial capacity of forty-one murderers was 1593 cc., also superior to the general average. The same result has been obtained through weighings of brains of eminent men. The brains of thirty-four of these showed an average increase of 163 grammes

over the average brain-weight of 1370 grammes. The force of the arguments furnished by these observations must, however, not be overestimated. Most brain-weights are obtained in anatomical institutes, and the individuals which find their way there are poorly developed on account of malnutrition and life under unfavorable circumstances, while the eminent men represent a much better nourished class. As poor nourishment reduces the weight and size of the whole body it will also reduce the size and weight of the brain. It is not certain, therefore, that the observed difference is entirely due to the higher ability of the eminent men. The difference between the cranial capacities of eminent men and of the general population is increased beyond its actual size by the difficulties encountered in determining the sex of skulls. Skulls of a number of men are always mistaken for those of women and *vice versa*, which tends to reduce the capacity for males, while it increases that of the females. As, in the case of eminent people, the sex is known accurately, it may be expected that the average capacity of the skulls of eminent men will be higher than that of skulls the sex of which is not known. It must be said, however, that Broca's measurements, the results of which are given above, show that he determined the sex of a skull with considerable accuracy. Another fact which may be adduced in favor of the theory that greater brains are accompanied by higher faculty, is, that the city population show higher capacities than those of the country; also that the observation that the heads of the best English students continue to grow longer than those of the average class of students.

While the force of these arguments must be admitted, a number of restricting facts must be enumerated. The most important among these is the difference in the brain-weight between men and women. When men and women of the same stature are compared it is found that the brain of the woman is much lighter than that of the man. Nevertheless, the faculty of woman is undoubtedly just as high as that of man. This is therefore a case in which smaller brain-weight is accompanied throughout by equal faculty. We conclude from this fact that it is not impossible that the smaller brains of males of other races should not do the same work that is done by the larger brain of the white race. But this comparison is not quite on equal terms, as we may assume that there is a certain structural difference between male and female which causes the difference in size between the sexes, so that comparison be-

tween male and female is not the same as a comparison between male and male. We will also remember that, although the brains of eminent men are, on the average, larger than those of the average individual, there are some small brains included in their number.

Notwithstanding these restrictions, the increase of the size of the brain in the higher animals and the lack of development in microcephalic individuals are fundamental facts which make it more than probable that increased size of the brain causes increased faculty, although the relation is not quite as immediate as is often assumed.

Assuming that capacity is nearly proportional to the size of the brain, we must remember that the average sizes of the brain of the white are numerously represented among other races. Middle-sized brains of whites may be represented by the group of individuals having capacities of from 1450 to 1650 cc. This group encloses 55 per cent of the Europeans, 58 per cent of the African negroes and 58 per cent of the Melanesians. The same result appears when we compare the number of individuals having great capacities. We find that 50 per cent of all whites have a capacity of the skull greater than 1550 cc., while 27 per cent of the negroes and 32 per cent of the Melanesians have capacities above this value. We might, therefore, anticipate a lack of men of high genius, but should not anticipate any great lack of faculty among the great mass of negroes living among whites and enjoying the advantages of the leadership of the best men of that race.

This, however, is hardly the correct standpoint, as mental ability certainly does not depend upon the size of the brain alone. The proper point of view of this question is brought out most clearly by Dr. H. H. Donaldson whose opinion I will quote. He says, "I consider the significance of the encephalon to depend upon the number and size of the cells composing it. In the negroes and lower races generally, the number of cells is probably less than in the white. This is mainly an inference from the total weight of the encephalon. Equally important are the final stages in the enlargement of the structural elements, stageswhich apparently have the result of bringing a larger number of elements into physiological connections by means of a very slight quantitative extension of their branches. Changes, which moreover can be followed, say in the cortex of the brain of the white in individuals

thirty or more years of age. When we compare the capacity for education between the lower and higher races, we find that the great point of divergence is at adolescence and the inference is fairly good that we shall not find in the brains of the lower races the post-pubertal growth in the cortex to which I have just alluded. As to the sculpturing of the brain surface by gyri and sulci we still lack any good racial characters."

We have now gone over the field of anatomical differences between races so far as they have a bearing upon our question. Our conclusion is, that there are differences between the physical characters of races which make it probable that there may be differences in faculty. No unquestionable fact, however, has been found yet which would prove beyond a doubt that it will be impossible for certain races to attain a higher civilization.

We must next examine the psychological characteristics of primitive people in order to discover if there are any which assign them a lower place among mankind. This investigation is exceedingly difficult and unpromising because it appears doubtful throughout which of these characteristics are causes of the low stage of culture and which are caused by it, or which of the psychological characteristics are hereditary and would not be wiped out by the effects of civilization. The fundamental difficulty of collecting satisfactory observations lies in the fact that no large groups of primitive man are brought nowadays into conditions of real equality with whites. The gap between our society and theirs always remains open and for this reason their mind cannot be expected to work in the same manner as ours. The same phenomenon which led us to the conclusion that primitive races of our times are not given an opportunity to develop their abilities prevents us from judging their innate faculty. On account of this insurmountable difficulty which seems to make all attempts at a satisfactory solution of this problem impossible, I will confine myself to a few fundamental points and suggestions as to the method by which this important question may be solved.

Numerous attempts have been made to describe the peculiar psychological characteristics of primitive man. Among these I mention those of Wuttke, Klemm, Eichthal, de Gobineau, Nott and Gliddon, Waitz, Spencer and Tylor. Their investigations are of merit as descriptions of the characteristics of primitive people, but we cannot claim for any of them that they describe the psy-

chological characters of races independent of their social surroundings. Klemm and Wuttke designate the civilized races as active, all others as passive, and assume that all elements and beginnings of civilization found among primitive people—in America or on the islands of the Pacific ocean—were due to an early contact with civilization. Eichthal considers human society as an organism and assumes that the white race represents the male, the negro the female principle. De Gobineau calls the yellow race the male element, the black race the female element and calls only the whites the noble and gifted race. Nott and Gliddon ascribe animal instincts only to their lower races, while they declare that the white race has a higher instinct which incites and directs its development. All such views are generalizations which either do not sufficiently take into account the social conditions of races, and thus confound cause and effect, or were dictated by scientific or humanitarian bias or by the desire to justify the institution of slavery. Tylor and Spencer, who give an ingenious analysis of the psychological faculty of primitive man, do not assume that these are racial characteristics, although the evolutionary standpoint of Spencer's work often seems to convey this impression. I think the true point of view has been expressed most happily by Waitz. He says, "According to the current opinion the stage of culture of a people or of an individual is largely or exclusively a product of his faculty. We maintain that the reverse is at least just as true. The faculty of man does not designate anything but how much and what he is able to achieve in the immediate future and depends upon the stages of culture through which he has passed and the one he has reached."

The descriptions of the state of mind of primitive people, such as are given by most travellers, are too superficial to be used for psychological investigation. Very few travellers understand the language of the people they visit, and how is it possible to judge a tribe solely by the descriptions of interpreters, or by observations of disconnected actions the incentive of which remains unknown? But even when the language is known to the visitor, he is generally an unappreciative listener of their tales. The missionary has his strong bias against the religious ideas and customs of primitive people, and the trader has no interest in their beliefs and in their barbarous arts. The observers who really entered into the inner life of a people, the Cushings, Callaways and

Greys, are few in number and may be counted at one's finger's ends. Nevertheless, the bulk of the argument is always based on the statement of hasty and superficial observers.

I will now select a few of the mental qualities which are most persistently claimed as racial characteristics of the lower groups of mankind. Among the emotional characters impulsiveness is considered the most fundamental. Most of the proofs for this alleged peculiarity are based on the fickleness and uncertainty of the disposition of primitive man and on the strength of his passions aroused by seemingly trifling causes. I will say right here, that the traveller or student measures the fickleness of the people by the importance which he attributes to the actions or purposes in which they do not persevere, and he weighs the impulse for outbursts of passion by his standard. Let me give an example. The traveller, desirous to reach his goal as soon as possible, engages men to start on a journey at a certain time. To him time is exceedingly valuable. But what is time to primitive man who does not feel the compulsion of completing a definite work at a definite time? While the traveller is fuming and raging over the delay, his men keep up their merry chatter and laughter and cannot be induced to exert themselves except to please their master. Would not they be right in stigmatizing the impulsiveness and lack of control of many a traveller when irritated by a trifling cause like loss of time? Instead of this the traveller complains of the fickleness of the natives who quickly lose interest in the objects which the traveller has at heart. The proper way to compare the fickleness of the savage and that of the white is to compare their behavior in undertakings which are equally important to each. Does not primitive man persevere wonderfully in the manufacture of his utensils and weapons? Does he shrink from privations and hardships which promise to fill his ambition of obtaining higher rank among his fellows? The Indian, fasting in the mountains, awaiting the appearance of his guardian spirit, the youth who must give a proof of his bravery and endurance before being accepted in the ranks of the men of his tribe may be adduced as examples. The alleged fickleness may always be explained by a difference of the valuation of motives and is not a specific characteristic of primitive man. Primitive man perseveres in certain pursuits which differ from those in which civilized man perseveres.

The same may be said of the outbursts of passion occasioned by slight provocations. What would a primitive man say to the noble passion which preceded and accompanied the War of the Rebellion? Would not the rights of slaves seem to him a most irrelevant question? On the other hand, we have ample proof that his passions are just as much controlled as ours, only in different directions. The numerous customs and restrictions regulating the relations of the sexes or the use of the food supply may serve as examples. The difference in impulsiveness may be fully explained by the different weight of motives in both cases. In short, perseverance and control of passion are demanded of primitive man as well as of civilized man but at different occasions. If they are not demanded as often, the cause must be looked for not in the inherent inability to produce them, but in the social status which does not demand them to the same extent.

Spencer mentions as a particular case of this impulsiveness the improvidence of primitive man. I believe it would be more proper to say instead of providence, optimism. "Why should I not be as successful to-morrow as I was to-day?" is the guiding thought of primitive man. This thought is, I think, not less powerful in civilized man. What builds up business activity but the belief in the stability of existing conditions? Why do the poor not hesitate to found families without being able to lay in store beforehand? We must not forget that starvation among most primitive people is an exceptional case the same as financial crisis among civilized people, and that for times of need, such as occur regularly, provision is always made. Our social status is more stable so far as the acquiring of the barest necessities of life is concerned, so that exceptional conditions do not prevail often; but nobody would maintain that the majority of civilized men is always prepared to meet emergencies. We may recognize a difference in the degree of improvidence caused by the difference of social status but not a specific difference between lower and higher types of man.

Another trait which has been ascribed to primitive man is his inability of concentration when any demand is made upon the more complex faculties of the intellect. I will mention an example which seems to make clear the error committed in this assumption. In his description of the natives of the west coast of Vancouver Island, Sproat says: "The native mind, to an educated man, seems generally to be asleep . . . . On his attention being

fully aroused, he often shows much quickness in reply and ingenuity in argument. But a short conversation wearies him, particularly if questions are asked that require efforts of thought or memory on his part. The mind of the savage then appears to rock to and fro out of mere weakness." Spencer, who quotes this passage, adds a number of others corroborating this point. I happen to know the tribes mentioned by Sproat through personal contact. The questions put by the traveller seem mostly trifling to the Indian and he naturally soon tires of a conversation carried on in a foreign language and one in which he finds nothing to interest him. I can assure you that the interest of those natives can easily be raised to a high pitch and that I have often been the one who was wearied out first. Neither does the management of their intricate system of exchange prove mental inertness in matters which concern the natives. Without mnemonic aids they plan the systematic distribution of their property in such a manner as to increase their wealth and social position. These plans require great foresight and constant application.

I will select one more trait which has often been adduced as the primary reason why certain races cannot rise to higher levels of culture, namely, their lack of originality. It is said that the conservatism of primitive man is so strong that the individual never deviates from the traditional customs and beliefs. While there is certainly truth in this statement in so far as customs are more binding than in civilized society, at least in its most highly developed types, originality is a trait which is by no means lacking in the life of primitive people. I will call to mind the great frequency of the appearance of prophets among newly converted tribes as well as among pagan tribes. Among the latter we learn quite frequently of new dogmas which have been introduced by such individuals. It is true that these may often be traced to the influence of the ideas of neighboring tribes, but they are modified by the individuality of the person and grafted upon the current beliefs of the people. It is a well-known fact that myths and beliefs have been disseminated and undergo changes in the process of dissemination. Undoubtedly this has often been accomplished by the independent thought of individuals. I believe one of the best examples of such independent thought is furnished by the history of the ghost-dance ceremonies in North America. I am indebted to Mr. James Mooney, a close student

of this subject, for the following opinion: "Briefly and broadly it may be stated that the more primitive a people, the more original their thought. Indian prophets are usually original as to their main doctrine, but are quick to borrow anything that may serve to make it more impressive. Heathenism is usually tolerant and the Indian sees no inconsistency in adding to his heathenism anything that he can borrow from Christianity." A few cases which have come under my own observaton are entirely in accord with this opinion; that is to say, the doctrine of the Indian prophet is new, but based upon the ideas of his own people, their neighbors, and the teachings of missionaries. The notion of future life of the Kwakiutl of Vancouver Island has undergone a change in this manner, in so far as the idea of the return of the dead in children of their own family has arisen. The same independent attitude may be observed in the replies of the Nicaraguan Indians to the questions regarding their religion which were put to them by Bobadilla and which were reported by Oviedo.

To my mind the mental attitude of individuals who thus develop the beliefs of a tribe is exactly that of the civilized philosopher. The student of the history of philosophy is well aware how strongly the mind of even the greatest genius is influenced by the current thought of his time. This has been well expressed by my friend Rudolph Lehmann in his work on Schopenhauer. "The character of a system of philosophy is, just as that of any other literary work, determined first of all by the personality of its originator. Every true philosophy reflects the life of the philosopher as well as every true poem that of the poet. Secondly, it bears the general marks of the period to which it belongs, and the more powerful the ideas which it proclaims, the more strongly it will be permeated by the currents of thought which fluctuate in the life of the period. Thirdly, it is influenced by the particular bent of philosophical thought of the period."

If such is the case among the greatest minds of all times, why should we wonder that the thinker in primitive society is strongly influenced by the current thought of his time? Unconscious and conscious imitation are factors influencing civilized society, not less than primitive society, as has been shown by G. Tarde, who has proved that primitive man and civilized man as well, imitates not such actions only as are useful, and for the imitation of which logical causes may be given, but also others for the adop-

tion or preservation of which no logical reason can be assigned.

Based on these considerations we believe that in the more complicated psychological phenomena no specific differences between lower and higher races can be found. By this, however, we do not mean to say that no such differences exist or can be found, only that the method of investigation must be different. It does not seem probable that the minds of races which show variations in their anatomical structure should act in exactly the same manner. Differences of structure must be accompanied by differences of function, physiological as well as psychological; and, as we found clear evidence of difference in structure between the races, so we must anticipate that differences in mental characteristics will be found. Thus, a smaller size or lesser number of nervous elements would probably entail loss of mental energy, and paucity of connections in the central nervous system would produce sluggishness of the mind. As stated before, it seems probable that some differences of this character will be found between the white and negro, for instance, but they have not been proved yet. As all structural differences are quantitative, we must expect to find mental differences to be of the same description, and as we found the variations in structure to overlap, so that many forms are common to individuals of all races, so we may expect that many individuals will not differ in regard to their faculty, while a statistical inquiry embracing the whole races would reveal certain differences. Furthermore, as certain anatomical traits are found to be hereditary in certain families and hence in tribes and perhaps even in peoples, in the same manner mental traits characterize certain families and may prevail among tribes. It seems, however, an impossible undertaking to separate in a satisfactory manner the social and the hereditary features. Galton's attempt to establish the laws of hereditary genius points out a way of treatment for these questions which will prove useful in so far as it opens a method of determining the influence of heredity upon mental qualities.

On account of this difficulty I do not enter upon a discussion of the characters of nations. Much has been said about the hereditary characteristics of the Jews, of the gypsies, of the French and Irish, but I do not see that the social causes which have moulded the character of members of these people have ever been eliminated satisfactorily; and, moreover, I do not see how this can be accomplished without previous investigations into the question as

to which groups of mental qualities are hereditary. A number of external factors may easily be named: climate, nutrition, occupation; but, as soon as we enter into a consideration of social factors, we are unable to separate cause and effect or external and internal factors. The first-named groups affect the physiological functions of the body and through them the mind. An excellent discussion of these influences upon the character of a people is given by A. Wernich in his description of the character of the Japanese. He finds some of their peculiarities caused by the lack of vigor of the muscular and alimentary systems which in their turn are due to improper nutrition, while he recognizes other physiological traits which influence the mind as hereditary. We may expect to find still more far-reaching effects of malnutrition which was continued through long generations among the Bushmen and the Lapps.

We know some of the correlations between physiological and psychological functions. It is clear, therefore, that where such correlation is known, the physiological phenomena which accompany the psychical traits ought to be made a subject of special study in reference to the question, whether the mental traits under consideration are hereditary or not.

The only feasible way of attacking the psychological problem while excluding social factors seems to be to investigate the psychical processes of great numbers of individuals of different races who live under similar conditions. This can be accomplished but has not been done yet to such an extent as to allow us to draw far-reaching conclusions. I mention that Professor Barnes and Miss Hicks found differences of favorite colors between children of different races and different ages; that attempts have been made to show that the minds of negro children cease to develop sooner than those of white children, although the results are not conclusive. Modest investigations of the senses and of simpler mental activities of children will give the first satisfactory answer to the important question of the extent of racial differences of faculty. The schools of our country, particularly those of large cities, open a vast field for researches of this character.

We have now one more point to consider, namely, the question if the faculty of man has been improved by civilization, and particularly, if that of primitive races may be improved by this agency. We must consider both the anatomical and psychological

aspects of this question. I have already pointed out that civilization causes anatomical changes of the same description as those accompanying the domestication of animals. It is likely that changes of mental character go hand in hand with them. The observed anatomical changes are, however, limited to this group of phenomena. We cannot prove that any progressive changes of the human organism have taken place, and particularly no advance in the size or complexity of the structure of the central nervous system caused by the cumulative effects of civilization can be proved.

There seems to be no doubt that the anatomical characters of the races have in all their main points remained constant. Kollmann has proved that the oldest remains of man found in Europe represent the types which are still found among the modern civilized populations. As our knowledge of the older types of Europeans is confined to their osseous remains, it cannot be expected that finer differences, even if they existed, would be found. The difficulty of proving a progress of faculty is still greater. It seems to me that the probable effect of civilization upon an evolution of human faculty has been much overestimated. The psychical changes which are the immediate consequence of the domestication or civilization may be considerable. They are changes due to the influence of environment. It is doubtful, however, if any progressive changes or such as are transmitted by heredity have taken place. The number of generations subjected to this influence seems altogether too small. For large portions of Europe we cannot assume more than forty or fifty generations, and even this number is probably considerably too high, in so far as in the middle ages the bulk of the population lived on very low stages of civilization.

Besides this, the tendency of human multiplication is such that the most highly cultured families tend to disappear, while others which have been less subjected to the influences regulating the life of the most cultured class take their place. Therefore, it is much less likely that advance is hereditary than that it is transmitted by means of education. I believe, furthermore, that educational influences, which include the general educating influence of social surroundings, are superficial as compared to hereditary causes.

In illustrating the improving effects of civilization through transmission, much weight is generally laid upon cases of relapse of individuals belonging to primitive races who have been educated.

These relapses are interpreted as proofs of the inability of the child of a lower race to adapt itself to our high civilization, even if the best advantages are given to it. It is true that a considerable number of such cases are on record. Among these I will mention Darwin's Fuegian who was educated in England and returned to his home where he fell back into the ways of his primitive countrymen; and the West Australian girl who was married, but suddenly fled to the bush after killing her husband and resumed life with the natives. These cases are true, but not one of them has been described with sufficient detail. The social and mental conditions of the individual have never been subjected to a searching analysis. I should judge that, notwithstanding their better education, their social position was always one of isolation, while the ties of consanguinity formed a connecting link with their uncivilized brethren. The power with which society holds us and does not give us a chance to step out of its limits cannot have acted as strongly upon them as upon us. On the other hand, the station obtained by many negroes in our civilization seems to me to have just as much weight as the few cases of relapse which have been collected with much care and diligence. I should place side by side with them the cases of white men who live alone among native tribes and who sink almost invariably to a semi-barbarous position, and the members of well-to-do families who prefer unbounded freedom to the fetters of society, and flee to the wilderness where many lead a life in no way superior to that of primitive man.

We have now considered the question in how far human faculty is determined by race from three points of view. We have shown that the anatomical evidence is such, that we may expect to find the races not equally gifted. While we have no right to consider one more ape-like than the other, the differences are such that some have probably greater mental vigor than others. The variations are, however, such that we may expect many individuals of all races to be equally gifted, while the number of men and women of higher ability will differ. When considering the psychological evidence, we found that most of it is not a safe guide for our inquiry, because causes and effects are so closely interwoven that it is impossible to separate them in a satisfactory manner, and as we are always liable to interpret as racial character what is only an effect of social surroundings. We saw, however, that investigations based on physiological psychology and experimental psychol-

ogy will allow us to treat the problem in a satisfactory manner. In these and in detailed studies of the anatomy of the central nervous system of the races we must look for a final solution of our problem.

Finally, we found that there is no satisfactory evidence that the effects of civilization are inherited beyond those which are incident to that domestication to which civilization corresponds. We know that these are hereditary to a limited degree only and that domestication requires only few generations. We did not find proof of cumulative increase of faculty caused by civilization.

Although, as I have tried to show, the distribution of faculty among the races of man is far from being known, we can say this much: the average faculty of the white race is found to the same degree in a large proportion of individuals of all other races, and although it is probable that some of these races may not produce as large a proportion of great men as our own race, there is no reason to suppose that they are unable to reach the level of civilization represented by the bulk of our own people.

PAPERS READ.

VARIATIONS IN THE HUMAN SKELETON AND THEIR CAUSES. By Dr. D. G BRINTON, Media, Pa.

[ABSTRACT.]

VARIATIONS in organic forms are generally explained as "reversions" or "retrogressive anomalies," when some immediate cause is not apparent. Such an explanation assumes an hypothesis which has not been demonstrated, and if any existing agency is sufficient to produce the result, it should be accepted in preference. This is illustrated by a review of variations in the human skeleton, some of which have been explained as "pithecoid reversions," others as "racial criteria"; when, in fact, they are merely the results of recognizable present activities.

First are Sexual Variations. While such exist, especially in stature and the shape of certain bones, there is really nothing infantile or semi-pithecoid in the female skeleton, as some have maintained.

Lateral Variations are connected with the phenomenon of right and left-handedness, for which we have no sufficient explanation. It has not been shown to be either racial or specific.

Mechanical Function is a prominent cause of osteologic variation. Instances of the result of *increased* function are physiological hyperostosis, platycnemic tibia, increased torsion of the humerus, and in many instances the relative proportion and forms of the face and the head. To *diminished* mechanical function should be referred numerous changes in the teeth, the loss of the third molar, and of the fourth tubercle on the other molars.

Another source of variation is Deficient Nutrition. This explains the dwarfing of stature, microcephaly, bifid sternum and the undue presence of epactal and wormian bones, and of multiple exostosis.

All these causes act more freely in savage conditions and in early periods of history; and for that reason, skeletal variations are most abundant in subjects subjected to the stress of such modes of life.

The conclusion is that because a variation in human anatomy is *pithecoid*, that is, that it is in the line of the organic development of a lower species, it by no means follows that it is *pithecogenetic*, that is, that it is a reversion to a simian ancestral type; but only that the conditions of existence of the human subject were in that instance more analogous to those of simian life.

ON CERTAIN MORPHOLOGIC TRAITS OF AMERICAN LANGUAGES. By Dr. D. G. BRINTON, Media, Pa.

[ABSTRACT.]

LANGUAGES are the product and expressions of organism, and themselves should be studied as organic entities subject to the recognized laws of such. On the other hand, they are not passive products of the human intelligence, secretions, as it were, but in turn act upon it powerfully and materially modify its development. Linguistic morphology investigates the fundamental traits of languages. The first distinction which it makes is between those which have, and those which have not, true grammatical forms. Those which are poor in these make amends by other processes, one of which is Incorporation, which various linguists have claimed to be the prevailing and characteristic process in American tongues. There is considerable misunderstanding as to what it really is. It is appropriate to explain, therefore, that incorporation is accomplished by the following grammatic procedures: —

1. The expression of the idea of Being, that is, the nominal, is subordinated to the expression of the idea of Action, that is, the verbal.

2. Inseparable pronouns and inseparable classifying particles are prominent in the language.

3. There is a tendency to the composition and derivation of verbs and verbals by the process of Infixation, by which inserted significant particles or new phonetic elements modify the meaning of the theme.

4. The clauses of a compound sentence are only superficially connected. There is no true grammatic subordination, the logical sequence is expressed either by position or material words, and relative pronouns are rare, or do not exist, those doing duty as such being, in fact, demonstratives.

The effects of Incorporation on the morphology of languages are characteristic and various. Some of the most obvious are as follows: —

1. A strong tendency to isolation of the sentence-elements, those not included in the verbal standing alone and unconnected.

2. A deficient development of case. Case-relations are either not expressed, or are expressed by material additions to the stem, or by particles separate from it.

3. An effort to present each clause of a sentence in one phonetic complex, that is, in one connected sound. This tendency leads to what some have called the *polysynthesis* of American languages. It is not essential to the incorporative method, and it is a great blunder to consider it synonymous with it, as some recent writers have done. It is merely an accidental aspect of the incorporative process.

SOME NOTES ON PAIDOLOGY. By S. EDWARD WARREN, Newton, Mass.

[ABSTRACT.]

As a word of preliminary explanation, I may state that reference to definitions of, and articles on anthropology, leave on my mind the impression that anthropology means the science of man, so far as he may be known by man,

through history, archæology, ethnology, and present observation, especially, perhaps of wild races; of man, then, from the point of view of natural history, as distinguished from revelation; or, finally, of man as natural, as one of the various creatures on the earth, rather than as spiritual.

If the emphasis on wild man as the distinctive subject of Anthropology be at all correct, then Sociology might distinctively treat of civilized man, — or cultivated man, as the term more properly contrasted with wild man.

Paidology may then mean so much of anthropology as relates to the study of childhood, or man, germinating, so to speak, feeling its way up into the light of conscious intelligent participation in surrounding civilization.

Though I cannot give facts concerning growth, measurement, sayings, doings, or tastes, of large numbers, yet the few here presented may fit in with those collected by others, and swell the aggregate from which deductions may be made.

My facts, moreover, *are* facts, personally known to me, and not newspaper, or hearsay reports of childhood's words or ways, put into their minds to say or do. They have impressed themselves permanently on my memory at various times, some, since the years before the war, and through my natural fondness for children.

But, now, without further preface, to proceed to my facts, except to add that they are not mere facts, like newspaper reports of children's bright sayings and doings, printed for the reader's amusement, but are accompanied by an attempt to show their significance.

Sense of defeat in being mastered, perhaps unaccountably, by what one instinctively feels that he ought to control, may manifest itself in various ways. It may be seen in a determination to conquer, or by asking to be shown how to do what is to be done, or by *rage at the humiliation of want of success.*

A little boy, of about seven, since able to drive a span in a hilly country, had his first toy wheelbarrow. Somehow he could not push it straight ahead as he wished, but helplessly followed it round in circles, as if it drew him as it would. At last such was his vexation that he lay flat on his back, kicking and screaming. Had an older friend been present, might not the simple suggestion to aim straight at a post, keep his eye on it, and make the wheelbarrow go there, have succeeded, after a few kindly supervised efforts, in helping him to make his wheel go anywhere he wanted it to go?

Little Juliet, partly of French descent, was born in the family where the writer was an inmate, at the time and for a few years after. The situation afforded a good opportunity for observing the development of the child mind.

In strawberry time, the rapid disappearance of the red berries from the dish, as others at the table were helped, aroused a fearful, tearful, and outspoken concern lest all would be gone before her turn came. At last, observing that each guest said "thanks" on receiving a saucer full, she sought to shrewdly *adapt means to ends*, by eagerly exclaiming, "'tawberry — 'tawberry — t'ank — t'ank." She was, however, more effectually quieted by assurances from those she fully trusted that she should have some, or that they would not taste theirs till hers were given to her.

Another example of *resort to "diplomacy"* when not three years old, was seen in her device for gratifying her fondness for cologne. Having probably had

cologne put on her head when severely bumped, she once toddled to the writer's study, after the least possible hit on the head, saying, "Unco [uncle], dat head boke [broken], put cologne on dat head."

Desire to feel one's-self of use and consequence, tendency to *imitate the doings of elders*, and a *special thought for one* who was very fond of her, all manifested themselves together in the childish mischief of spattering herself and the floor, by smartly patting with wide open hand a tub of soaking clothes, while she said with much more satisfaction to herself than to anyone else, "Baby help Biddy wash the clothes; Baby wash unco's han'siff; Baby work like a dog."

Harry —— was a jewel and a darling, also in his third year, and one of the principal sources of entertainment during a summer sojourn in a rather barren and monotonous and hence unattractive region more than twenty years ago. The workings of his mind were the amusement, and sometimes the wonder, of all the company. One day, a new boarder, a bland old gentleman, arrived. A few mornings after, when Harry said good-morning, as usual, to his friends at the breakfast table, I said to him, "Why don't you say good-morning to Mr. K ——?" the new comer. After an instant of meditation on *social propriety*, he said, "I ain't akainted" [acquainted]. Thereupon a formal introduction took place and after that "good morning, Misser K——" took its place with the other salutations.

"*More scared than hurt*" is a familiar thought, and the same little fellow seemed to have a dim perception of the truth when, after the jar of some misstep or other such trifling accident, he answered the kind inquiries as to whether he was hurt by saying, "I ain't hurt, I 'se fite-ened" [frightened].

On another occasion, his circle of closest friends could not make up their minds whether it was *sense of guilt, and a desire to see justice have its due* even on himself, or a hope of *working on his mother's sympathies*, that made him say, when guilty of some infantile misdeed, "Mamma, s 'ut me up, s 'ut me up."

A recent sketch of life in the Tuileries under the second empire intimates that the emperor secretly felt that he kept his place through a succession of devices for diverting the mind of France, whether by a reconstruction of Paris, or by a brilliant stroke in Lombardy, and hence that *sometime the end must come*. So our little Harry, who was inseparably attached to his mother, could not endure the thought of going to bed alone, or without his mother's companionship at bed-time; yet he felt that the time must come when he must do so. So, when a little pressed with teasing questions as to when that time would come, he said, "bye and bye when he wears pants"—and that time seemed a comfortable way off.

The place was still and dull, and Harry had no child playmates. So one day I took him on my shoulder to a patch of corn, in which—New England fashion—pumpkins were growing. These, when rapped with the knuckles, gave a dull hollow sound very faintly musical. Here Harry found what the callous idlers of the town are always in search of—a genuine *new sensation*, so that for some weeks afterwards, whenever I asked him where I should take him, or what he would like to do, he would say: "pat the pumpkins."

Once more: *Relief in tears* is a familiar thought, expression, and experience. Harry understood it. When disquieted by a sudden hurt, or fright which gave a rude shock to his little spirit, no matter how kindly the encouragements of his

friends not to mind it, and their assurances that nothing was the matter, he would sometimes say, "I must ky," and when he had had his little quiet "ky," all would be serene again. Other children might cry in like manner. Not many however, would, I think, be able to express the necessity for so doing, by saying, "I *must* ky."

Little M—— was a little girl also in her third year. I was with her for a much shorter period than with Harry, and saw less of her every day. But two characteristic points were worth noting, the beginnings of *true feminine regard for personal appearance*, and of *fondness for fashion considered as uniformity* of *action*, or conformity to custom.

One day at table, detecting others, as she believed, smiling at her face somewhat discolored with blueberries, she laughingly hid her face in her hands and bowed her head to conceal her appearance, which, however, her berry-stained fingers failed to improve.

Then, at another time, when a small wave of dread of singularity seemed to pass over her mind, she takes her cup and says: "Mamma drink, Papa drink," and so on to "baby drink, all drink."

Coming now to children a little older, but still within the period of *spontaneity*, or that of impulsive, or *mostly unpremeditated* action, and of *objectivity*, or absorption in external things, I will mention the case of V——, a ten-year old New-Hampshire boy, who was for several weeks at one time, and for seven months at another, under my daily observation.

He was a half wild child of nature like Whittier's "bare-foot boy," and whose whole being was summed up in the one word, love of motion and of vigorously moving life.

He was from a region where the characteristic compound of brightness and brass called "smartness" was highly appreciated, and where, sometimes, there was more of it than of scrupulousness, though there was also abundant good nature and hospitality. In the interval of a little more than a year between my two periods of daily association with him, he seemed to have rapidly caught this spirit in some of the life about him, so that, as was often observed, one of his most, if not the most prominent of his traits was irrepressible and long-continued delight at seeing others "get caught," together with a desire not to get caught himself. Hence he was at the first part of the second period *phenomenally reckless of truth*, when certain ends were to be accomplished, though apparently he improved greatly in this respect, after repeated, earnest, painstaking instruction, with constant example of outspoken frankness and truthfulness in those about him.

His wits were far more developed than his affections, especially than anything approaching tenderness. In fact he seemed incapable of tears under any circumstances, whether of pain, or grief. He was unmoved by caresses, and showed no fondness for them, yet when it was sought with self-evident sympathetic interest to reach his heart through his wits in a lively or entertaining way, and make him see with pleasure that one course of action was better than another, he would clasp his friend's neck, hug him tightly to his breast, and bestow hearty kisses on him.

Loving motion as he did, it must, however, be *free*, not *constrained* motion. He did not love *work* of most kinds, especially if done alone — as distinguished

from *play*, though he enjoyed chopping light pine boxes to pieces, if only to hear the rattling sound, use the keen new hatchet, or see the pieces fly. Or he would enjoy work done with another much older than himself, if ways could be found to make play of it, as when autumn leaves were raked up to make a large bonfire in a chilly evening, and if he was merrily wheeled in a great basket of leaves.

But the natural reward of such intrinsically dull *labor* as picking up stones, or pulling weeds, viz., that it accomplished the *work* of leaving the garden in a condition pleasing to the eye and gratifying to the sentiments of neatness and order, he could not appreciate. He was singularly *destitute of interest in beauty;* the florist's richest show-window of flowers he turned away from with indifference, if not disgust, and no attempt to interest him in the fine beauty of color, form, and striping of a carnation met with any success.

But, if a man, hurrying to catch a street car, felt the paper bag of peaches in his hand tearing and saw the peaches just ready to drop out on the sidewalk, and by a quick adroit stoop and under stroke, catch the bag underneath, and save his fruit and the car-trip, the comic realities, and still more comic possibilities, of the scene made such an impression on the boy that, for days after, he would laugh uncontrollably over it, and would do the same, even months afterward, when playfully reminded of it.

Books had painfully little attraction for him, as compared with some boys of his own age, except the pictures in them, and unless they were stories full of lively action. But his run, his straight up throw of a ball, and his delighted intentness in building a snow hut were a sight to see, and, rather curiously, his bureau drawer of the little things of a small boy's wardrobe were always a model of orderliness, and would have done credit to the most particularly nice little girl. Thus his faults and his virtues were in spots, and his nature was unevenly developed.

As just one more illustration, confirmatory of love of vigorous action as his absorbing passion, I may mention that I once took him to the organ chamber, after service on a church festival day, to see the skilled organist vigorously using both hands and both feet in playing a fine piece. "I wish I could do that," he exclaimed, and several times afterwards expressed wonder and interest in the performance. But it was the muscular skill, and exact quickness of the various motions that delighted him most, and not the music, as he himself declared in answer to particular inquiries.

Poor boy! when he could not enjoy the shaven lawns, and the confinement to the streets which they occasioned, he was glad to return to the free half-wild life of the hills, where the chipmunks are in the walls, and trees close to the house; where no fastidious lawn says, "Don't step on me," and where the little red schoolhouse for ten scholars, or less, stands in a raspberry thicket by the rough roadside. Verily, in this the boy might well be our master, and a little more of nature's motherly wildness and free undress might better surround all our suburban dwellings.

The fact that *the sports of childhood are, first, imitative* — playing horse, playing house, playing school, or store — may be too familiar to be mentioned. Yet some exhibitions of this fact called forth by local circumstances are worthy of passing notice. Thus, in the writer's boyhood, an *annual celebration of the surrender of*

Cornwallis at Yorktown was made by a sham fight between the country yeomanry in mongrel attire and arms, and the uniformed militia, representing the British. Such occasions, together with the Fourth of July, were especially stimulating to the manufacture of newspaper steeple caps, shingle swords, tinsel epaulettes, by the small boys whose shrill cries summoned to instant surrender.

Again, a boy whose life has been nearly coeval with that of American railroads, and who was born and brought up within a few rods of what is now a great railroad, found untiring sport in *playing railroad*, alone or with others. A wheelbarrow, empty and without its side-boards, represented the passenger trains. The same, with its side-boards, and laden with miscellaneous articles from the woodshed, and drawn slowly with mighty puffings, represented the freight trains; while, to make the imitation more perfect, the wheels of a worn-out baby wagon were set on to the front ends of the wheelbarrow handles to represent the cylinder heads of the engine.

Then, again, it once happened that *two rival villages* were provided with new and better hand fire-engines at about the same time. Numerous trials of strength between their companies followed. The smaller schoolboys from those villages caught the spirit, and had their trials of strength by pulling at opposite ends of a pole. The best village, of course, was the one whose boys could pull along the boys pulling against them at the other end of the pole.

Only two more notes shall end this brief contribution. They point to the fact that *indications of one's life pursuits may appear quite early.* K. and W. sat at one time side by side in the schoolmistress's village school. They sometimes beguiled spare moments by drawing on their slates. K.'s drawings were always true pictures, that is, perspective sketches, as of front or three-quarter views of horses and wagons, vessels, etc., and he has become distinguished as a wood engraver. W.'s drawings were oftener of locomotives than of anything else, but whether they were of horses, houses, vessels, or other objects, they were almost invariably side elevations, with little or no pictorial or perspective character. He, following out the bent thus shown in early childhood, was for many years a teacher and writer on the geometry of such purely mechanical drawing, and on geometrical perspective as distinguished from free-hand perspective, trusted to as correct by faith in the accuracy of the artist's eye.

Again: In some of the earlier volumes of the Atlantic Monthly will be found some thrilling articles of adventure, entitled "Mountaineering in the Sierra Nevada." One of the party mentioned in them was once a pupil of mine, and he told me at a chance meeting a few years later, that when a boy he made it a point never to walk on the ground when he could find a fence to walk on, and the higher the fence the better it suited him. At least this was the spirit, if not the exact wording of his remark, so enthusiastic was he on the accomplishments of cool-headedness, and surefootedness in dangerous places. Thus, the light blue-eyed boy fence-walker, as remarkable for blameless quietness as for fearlessness, became the enjoyer of situations the bare description of which is enough to make one's flesh creep.

Every conceivable human faculty seems to be arranged on a scale; and each individual man's place on each scale seems to lie anywhere between zero and almost infinity. The writer confesses to a place on the scale of fearless climbing, much nearer to zero than that of our hero of mountaineering, but remembers curious

attempts to do what he could, though he was far enough from being able to do what he would. In one corner of his father's barn was a bay, perhaps fifteen feet square and ten or twelve high, crossed by a beam about nine inches square. To get from a ladder on to this beam and cross the empty bay to the scaffold, and thus be compelled to recross the beam and get from it to the ladder, was his chief boyish act of "nerve" discipline. This small feat would be hardly worth mentioning except in connection with another, which in contrast seems almost unaccountable, and relative to which a comparison of experiences would be interesting. Though thus so timid, constitutionally, on all artificial heights, yet, strange to say, the writer has repeatedly looked into the abyss of Niagara, standing on Table Rock, or on the point of Goat Island, close to the end of the American Fall, yet without a fear or the thought of one.

These few miscellaneous notes of a few facts in paidology are insufficient for an induction. Yet they may be useful in two ways: first, as encouraging others to ransack the forgotten cupboards of memory for childish phenomena, so as to contribute to an aggregate of facts from which some principles may be deduced; second, they may show us how to trace the stream of our lives to their source, and to learn from what and with what we began, to cause to "look unto the rock whence ye are hewn, and to the hole of the pit whence ye are digged," so that it may be known why we are as we are, and what we are; how we were first built, or are now rebuilding ourselves as we are doing.

THE CHILD OF THE FUTURE. By Mrs. LAURA O. TALBOTT, 927 P Street, Washington, D. C.

[ABSTRACT.]

THERE is much talk of educational systems, they rise and fall like all fashions, but the *little child* comes to us year by year in its helplessness, and pleads with us to save it from the misery of its fathers.

We do not expect at once to convert Public Opinion to a better mode of treatment and development of very young children, wherein lies the hope of the future of all civilization. Can we hope for a future advanced condition of our race unless some efforts are made to prepare the child for a higher plane of life?

We are doing nothing for children under four years of age, the most receptive period of the human mind.

There is one thing certain about the child of the future, his personal equation will be required to be more elastic in order to adapt itself to a broader and more liberal manner of living than that of his progenitors. Very rapid evolution is taking place in the life of to-day. Will not those children need broader grasp, firmer touch, and greater directive power to reach and maintain the level allotted to them.

Experimental psychology is endeavoring by scientific investigations to ascertain the tendencies of the child nature, but of the evolution of thought power but little is known, and how will it be ever known if not by scientific study of the development of the child mind?

It is coming to be the conclusion of thinking persons that we shall never make much progress in our difficulties as a nation until our children receive an education that will make them independent thinkers.

The press remarks that the ambition of children is roused beyond their ability to fulfil their desires. We might also inquire if there is not too much machinery, and too much cutting out after the same pattern, to the utter *destruction* of all originality.

How few of our people use their minds in reflection; how they run in grooves; and it is almost an impossibility to get a new idea into their heads. Life is too short to spend ten or fifteen years in memorizing facts without cultivating the power of generalization.

Take a child whose observing powers have been awakened to an intelligent appreciation of Nature, and you will have to go far to see such a one become an outcast from society. Surely such nature work is adapted to enlarge the thinking powers of the mind.

Each child has its own temperament, and each temperament its particular tone; the study of this temperamental tone as elevated or depressed is one important point in a young child's development.

What immense reformatory institutions are erected by our cities for control of refractory youth! how much better for the State to appoint women experts as physicians in each precinct of the city, as investigators of conditions of child life! Difficult at first, it would soon come to be recognized as an essential part of the municipal system, even as police matrons are recognized in our cities.

The results of bad environment of little children is of immense disadvantage for the State. Why could not some preventive means be used?

The State can afford to employ teachers of foreign languages and of other means of culture, but not able to employ judicious caretakers for young children.

Scientific methods must come to prevail, that each individual may receive its fair treatment in the advance of civilization, that shall give the child every possible opportunity to become pure, honest, peaceable, self-sustaining, and possessed of independent thinking powers that will ever prevent its becoming a tool of political, financial, or seemingly religious corporation.

SURVIVALS OF DWARF RACES IN THE NEW WORLD. By R. G. HALIBURTON, 99 State Street, Boston, Mass.

[ABSTRACT.]

IT may be well to explain that the word *Pygmy* is merely a nickname for a dwarf. The old English form of it is like that in use among the Arabs, "a *Thumb*," *i. e.*, as "high as your Thumb," a "Tom Thumb," a "Hop-o'-my-Thumb." In Greek it was *Dactyl*, "a finger."

As only three years have elapsed since the announcement of the existence of dwarfs south of the Atlas was made, and two years only have passed since I drew attention to dwarfs in the Pyrenees, a few preliminary remarks may be neces-

sary before discussing the subject of survivals of a dwarf race in America very similar in many respects to those of the Atlas and the Pyrenees.

Till Schweinfurth's great work, "The Heart of Africa," appeared in 1873, it was assumed that the Pygmies were mythical, and when he described a regiment of them which he saw among the Mombuttu, near the Albert Nyanza, he was derided by not a few as an impostor.

Eighteen years later my statement that a very similar race existed in the vast region between the Sahara and the Great Atlas, was vehemently denounced, and in acrimonious editorials the "Times" and the "Standard" criticised my paper on "Dwarfs and Dwarf Worship," read before the Ninth Congress of Orientalists (1891).

The Congress awarded the author of the paper a medal.

Professor Sayce, one of the most eminent Orientalists of the age, wrote subsequently, "Your name will be henceforth attached to the discovery of dwarf races in North Africa, as Schweinfurth's has been to that of the dwarfs of Central Africa. I wonder if your dwarfs have anything to do with the Neolithic people, who carved the forms of animals, birds, and men on the sandstone rocks of North Central Africa, when the Sahara was a fertile plateau."

A year later the conclusions come to in my paper were unexpectedly verified by an *a fortiore* argument, based on the discovery not only of a dwarf tribe residing in the high ranges of the Atlas almost in sight of Morocco City, but also of a pygmy race far to the north of Morocco, in the Eastern Pyrenees and other localities in Spain.

This fact was also for a time disputed by a writer in the Academy, but no one now questions it. Mr. David MacRitchie, the well-known authority on the Ainos and the little "underground people," and builders of so-called "Fairy mounds," "Picts Houses," etc., in North Britain, was induced in May last by me to visit the Eastern Pyrenees, and his account of the little people that he saw there will soon appear. In May also I succeeded, after a two years' search, in procuring a paper in Spanish by Professor Miguel Morayta giving a very clear and precise account of the Pygmies of the Val de Ribas, who, he says, are looked on by their Catalan neighbors as belonging to a distinct race, and are called by them "*foreigners*," or "wonders" (*fenomenus*), as well as *Nanos* or *Nanus*. He says that they have Mongolian or Tartar eyes, square flat faces, and flat broad noses, and are from 4 ft. to 4 ft. 8 in. in height. A majority of them, when they reach 24 years of age, suffer from *goître*, and are called Cretins, but Cretinism does not attack their larger neighbors, who for many centuries have lived near them. *Cretinism*, in the Pyrenees and the Alps, it seems to me, is *racial* in its character, and is not a *disease*, but a *symptom* of decadence in a moribund race of dwarfs, who in the recesses of mountains are slowly going through the process of *dying out* through failing vitality, just as many centuries ago their race must have died out on the plains of Europe and Asia.

This can, I think, be easily accounted for by the fact that everywhere dwarf races are born hunters, and therefore flesh eaters, who, when deprived of their nutritious food by being driven from their hunting grounds, in time lose their superabundant vitality and agility, and die out, just as plants and trees do when the soil no longer supplies them with proper nutriment.

I now turn to the subject of the survival of an early dwarf race in the New

World, which from like causes may have also died out nearly everywhere. The natives of Hispaniola told the companions of Columbus that the first created race were dwarfs, who were feeble and died out, and became Cemis or guardian spirits.

In 1888, only a few months after my hearing of the Atlas dwarfs, I was told by the governor of St. Helena of a Chinese-looking little race that invaded British Honduras in 1882. I subsequently tried in vain to get some further information as to them, until I asked a Guatemalian general, with whom I crossed the Atlantic, if he knew anything about them. He informed me that he had commanded an expedition against them; that they were Pagans, and very savage, and would neither give nor accept quarter, and that in consequence of the danger of keeping them prisoners, they were always shot when captured by his men; that they were from four feet to four feet six inches in height, had human sacrifices, and used poisoned arrows, and blow-pipes. A point of special interest relating to them deserves mention; — There seems everywhere to be an hereditary aptitude for plaiting, or weaving mats, etc., in dwarf races, such as the Andaman Islanders of the Indian Ocean, the dwarfs of Southern Morocco, and in some places the Nanos of Spain, whose occupation is "making mats of Esparto grass;" — the "Panama hats," of world-wide fame, are not made at Panama, but on the river *Garrion*, on the frontier of British Honduras, by these dwarfs.

A dwarf tribe in Southern Morocco is called *Ait Gerouan*. In 1882, in a paper read before the A. A. A. S. by myself, on "Mount Atlas and its Traditions," I mentioned that the story of Hercules stealing the flocks of Geryon came from Southern Morocco. It is interesting to note that the Egyptians and the Greeks often represented Hercules as a dwarf, and that the Spanish Nanos principally reside in the province of *Gerona*, and not far from the district and the head waters of the Garonne. The scene of this myth is supposed by some ancient writers to have been in the eastern Pyrenees.

After my Guatemalian informant reached Europe I endeavored in vain to get further information from him. Last year, however, on making inquiries as to these dwarfs at the Colonial office, I was told of a gentleman named Mr. Blancaneaux, who had lived among them, and who afterwards wrote me a long letter giving me much information, but, unfortunately, when I wished to get further details, I found he had returned to his home in the interior of British Honduras.

He said that he had heard of the expedition of my Guatemalian informant, but that he believed that the origin of the trouble had been in promising the savages too much, and performing too little. He gave them a very high character, and said that there need be no difficulty with them so long as they are justly and truthfully dealt with. He described the height of the Mayagan as "for the most part five feet and under," but he did not specify the exact height of the Lacoutou, though he spoke of them as "of the same stamp."

As my Guatemalian informant described the Lacoutou as from four feet to four feet six, and Sir William Flower says that a race that does not exceed five feet three inches in height may be classed as a dwarf race, and as apparently none of these people are larger than the Andaman Islanders or the Bushmen, there can be no question that they are true dwarfs.

The *Mayagan*, so called from their having come from the Maya country, Yucatan, cultivate the soil and use firearms, but the warlike *Lacoutou*, of whom the Guatemalian general spoke, use only poisoned arrows and blow-pipes. They are also called *Masewal*. [A dwarf tribe of the Kalahari Desert, South Africa, is called *Masawar*.] They are redder in complexion than the Mayagan. Mr. Blancaneaux says that all the tribes that he has seen are more or less mixed with the blood of the Lacoutou, who are of the same stamp as the Mayagan. They live near the dividing line between Guatemala, Yucatan, and British Honduras. Like other dwarf races, they have a prominent abdomen, and have eyes resembling those of the Chinese, a peculiarity which is observable in nearly all dwarf races. They have, too, a knowledge of plants, and of the healing art, which also is a part of the traditionary lore of pygmy races. The incantations and dances of the Cinghalese Veddahs (called "Devil dancers") are almost precisely the same as those practised by South African dwarfs.

Are M. de Charnay's "Lacondon" of Yucatan, whom he describes as of medium height, the same as the Lacoutou of British Honduras? Perhaps Mr. Blancaneaux's "Lacoutou" should have been read "Laconton." The description of them, however, by the Guatemalian General has been indirectly confirmed, in more than one particular, by the account given by Mrs. Le Plongéon, in her "Up and down Yucatan," of the capture by woodcutters, "near the frontier of British Honduras," of a very small dwarf woman, (oddly enough) described by them as "wearing a large hat." In the hope of getting a sight of her tribesmen, the woodcutters sent her back to them with presents.

"The buildings on the Eastern coast, and on the Islands of Mujeres and Cozumela give evidence of habitation by a diminutive race. 'Tradition among the Indians refers frequently to the Aluxob (pygmies), and they ascribe all the monuments to them.'" (See Proc. of American Antiq. Socy., Ap. 24th, 1874, p. 71.)

The "Illustrated American" (N. Y.), of Sept. 22, 1894, announces that that enterprising paper is about to send a party to explore those curious ruins on the Andes known as "the city of the Pygmies."

Mr. A. H. Gatchett, in his "Ethnographic Sketch of the Klamath People" (contributions to N. A. Ethnology, Smithsonian Institution, vol. II. p. 1, xcix.) says: "Miraculous dwarfs are mentioned under the name of *Nahnias*, whose footprints, as small as a child's, are sometimes seen on the snow-clad slopes of the Cascade Mountains. But the dwarfish creatures who make them can only be seen by those who are initiated into the mysteries of witchcraft, and who by such spirit-like beings are inspired with a superior knowledge, especially in their treatment of diseases." "Another dwarf genius, about four feet high, lived on Williams River. The Klamath appear to know certain spirits of diminutive size, but the characteristics of such are not distinct enough to permit identification with the fairies, Erdmännchen, or Kabeiroi, of European mythology." These, however, I have shown were originally dwarfs. The oldest and most venerable institutions of antiquity were "the mysteries of the Cabiri," and the oldest God of Egypt, the Creator, Ptah, was a dwarf, and is called "*the Revealer*."

It cannot be a mere coincidence that at Uxmal, only a few hundred miles

from the region to this day inhabited by the dwarf Lacouton, and Mayagan, we find that one of the finest specimens of American architecture is called "the *House of the Dwarf.*" The legend connected with the building carries us back to the Egyptian dwarf God Ptah, for in it we are told of a dwarf Deity, who was born of an egg. Ptah, however, gives "the egg of creation" to Knum, who out of it fashions the world.

All this points to the existence of a dwarf race in early ages in the New World, who were objects of veneration, as was the case in the Old World. This view is confirmed by numerous representations of dwarfs recently brought to light by the explorations conducted by the Peabody Museum.

One of these is so remarkable that it is deserving of note. The face is square and broad and flat. The eyes are Mongolian; the cheeks bulge out so that they are more prominent than the nose, which is broad and flat. The resemblance of this dwarf to the Nanos described by Professor Morayta can hardly be accidental. "Their height [he says] is about four feet, or one metre and ten or fifteen centimetres. . . . They are very broad cheeked, which makes them look stronger than they really are. In general they all walk inclined forward. . . . Their features are so characteristic that when we have seen one we think we have seen them all. They all have a red complexion, and red hair, but like that of a peasant who does not comb or take care of his hair. They have a round face that is as wide as it is long, but the cheek bones are very prominent, and the jaw bones strongly developed, which makes their faces seem square. To this square look the nose contributes. It is flat and even with the face, which makes it look like a small ball, and the nostrils are rather high up. The eyes are not horizontal, the inside being lower than the outside, and they look like the Chinese, or rather like the Tartar race. To this must be added that they have no beard, four or six hairs, not of a beard but of down, being all they have on their face. Their faces are fleshy, but flaccid to such an extent that they seem to have no nerves, which causes a good many wrinkles, even when they are young. To make it clear, I might say that these people have the face of an old woman. The men and women are so alike that I could not help thinking of the tradition that the Chinese men were recommended to dress differently from the women. If the *Nanus* were all to dress alike, it would be difficult to tell the men from the women. Their very large mouth helps to give them a strange appearance, with their very thick lips, which never cover their long and strong teeth. Their incisors are remarkable for length and strength. Their lips are always wet, as if they had too much saliva, which to my mind makes them very repulsive. . . . It may prove that the existence of this race at Ribas may end in showing that in very remote ages there existed in Europe a Tartar race which hitherto has not been discovered."

It is a curious coincidence that Professor Putnam, in sending me a photograph of this dwarf (a sculpture in limestone), which is here reproduced, calls its subject "*a dwarf woman.*"

It will be noticed that the familiar sign of the T (Tau) cross is on the forehead. It was evidently a symbol of safety and of healing, and it is still the badge of "the medicine man" in Northwestern America. Ezekiel uses the word "*tau*" when he says that those will be saved from the destruction he predicts, who have the "*tau*" (in our version "sign") marked on their

foreheads. The early Dutch writers on the Cape of Good Hope, describing a species of worship among the Hottentot Bushmen, said that they retired into a cave, and marked each other on the forehead with the sign of the cross. Mr. Lummis, in his "Land of Poco Tiempo," gives a plate of a headdress worn by women at a Pueblo festival, which is represented as having a "*tau*" cross on it over the forehead. [Among the Tarahumari, "with a firebrand the medicine man makes three crosses on the child's forehead, if it is a boy, and four if a girl." See Scribner's Mag. Sept. '94, p. 298.]

There can be but little doubt that before long dwarf tribes will also be found to exist in South America. Two years ago I was informed by Mr. Cunninghame Graham, who had lived for years and travelled much in the Argentine provinces, that it was believed there that there are dwarf tribes living on islands in a vast lake in Uruguay at the head waters of the La Plata. I am reminded of this by the statement of a friend, that about 1869 he saw an article in a magazine which described that lake, and stated that occasionally portions of floating islands have drifted down the La Plata, bringing sometimes wild animals with them, and on one occasion a dwarf family.

The description given by a traveller at the World's Fair of a pygmy race of hunters whom he had met to the south of Brazil, and the persistent rumors, that have reached the archæologists of the Peabody Museum, of the existence of dwarf tribes and dwarf buildings on the east side of the Andes, give some confirmation to these stories.

[NOTE. — A paper read, almost simultaneously with the above paper, at the British Association by Professor Kollmann, described the discovery of the remains of a Neolithic race of dwarfs in Switzerland, which he supposed once

populated Europe. He also mentioned the recent discovery of a Pygmy race, about 4 feet high, living in Sicily; and he conjectured that Pygmies may have been the precursors of the larger races of men. — R. G. H.]

DWARF KLICKS. — A few observations on the existence of klicks, and their connection with dwarf races, may be of interest, as it is a subject which no one has looked into except myself.

Until my discovery of these klicks in Southern Morocco, and subsequently in Spain, it had been assumed that they were peculiar to South Africa. They are simply defects of articulation, the sound of which is so peculiar that it cannot properly be described in writing.

One of them, however, which is the most common, is somewhat simple. I first heard it without suspecting what it was, when I endeavored to write down the name of the tribe to which a native of the Dra Valley, south of the Atlas, belonged. I wrote it down "Psecht;" it ought to have been "Pecht." The klick introduced a sound like "s" or "ts." I supposed that the odd spasmodic action of the tongue, with which the sound was accompanied, was the effect of some nervous affection of the throat or tongue.

Klicks in South Africa are sometimes called "Bushman klicks," for the Bushmen and Hottentots have a large variety of them, a few of which have been inherited or borrowed from them by the Kaffirs. My revered friend, the late Dr. Moffat, the father-in-law of Livingstone, and a missionary in South Africa for half a century, and one of the few Europeans who could pronounce them, often amused me by repeating them to me.

A few years ago a friend who had lived in South Africa, and also at Mogador, the most southerly place in Morocco accessible to Europeans, casually remarked that he had often wondered how the Bushmen had in early times found their way as far north as Southern Morocco, the people of which he was convinced used "Bushman klicks."

My discovery of racial dwarfs, very similar to those of South Africa, in the vast region between the Great Atlas and the Sahara solved the mystery.

I have since that found that these klicks are in genèral use there, and are known as "eating words," but are quite unknown north of the Atlas.

But unexpectedly the range of these klicks was found to extend as far north as the Pyrenees.

While I was residing in a coast-town in Morocco, a Barbary Jewess from Mogador, who understood Spanish, and the dialect of Southern Morocco, told me that she had been surprised at finding an old Spanish woman who "*ate her words just like a Susi.*" I told her to find out where the old woman had got her klicks, for though she was above the ordinary size, I suspected that she must have dwarf blood in her veins. When asked the question by my informant, she said that she had got them from her "Nano ancestors." Dwarfs are called in Spain *Nano*, or *Nanu*, and sometimes (incorrectly) *Enano*. It turned out that she had the eyes and face of a Chinaman, or a Tartar, and that her only child and her grandchildren were Nanos, none of which much exceeded four feet in height, while several were less than that. At that time one of her granddaughters, only three feet ten and a half inches high, was playing with children

at the door of my hotel, and looked like a child of eight years of age, though she was over fourteen, and therefore a woman, for children at twelve or thirteen years of age marry in that country. She died in May last, and I was told that she had not grown any taller since I had seen her in 1891.

In Spain they have the same phrase that we find in Morocco for klicks,—"eating words." That klicks are not caused by any physical defect is clear from the fact that the old woman, who was brought up in the mountains of Murcia, has these klicks, while her little daughter and grandchildren, who have been brought up at a seaport, Malaga, with ordinary Spanish children, have no trace of them.

The belief of the Klamath people in the existence of mysterious dwarfs in the Cascade Range, and the occurrence of klicks in the language of a Northwest tribe described in the Smithsonian "Contributions to N. A. Ethnology," lead us to suspect that this tribe has inherited dwarf blood, or has resided in the vicinity of a dwarf klick-using people at some period of its existence.

Of course, if klicks only exist in North and South Africa and Spain, in the Old World, and yet are found in a part of the New World in connection with a dwarf race or its offshoots, it might point to an Eastern origin for the latter. But that klicks are not known to exist elsewhere is not the slightest evidence that they may not really exist, for nothing is more remarkable in the history of scientific investigation than the ignorance of even competent observers as to wayside truths that have not been sought for by them, or brought to their notice. Now that attention has been drawn to dwarf klicks, it is probable that they will be found in many ancient dialects, and especially in the languages of the dwarfish tribes that are found in Northeastern Asia.[1]

Are klicks of dwarf origin, and entitled to be called "Dwarf klicks?" But for my having adopted this assumption, I should never have known that my large-sized Mongolian looking Spanish informant was a half-breed *Nana*.

The name *Nahnias* for the legendary dwarfs of the Cascade Mountains is no doubt a corruption of the Spanish *Nano* (fem. *Nana*).

SOUTHERN VISITS OF THE ESKIMO. By Rev. W. M. BEAUCHAMP, Baldwinsville, N. Y.

[ABSTRACT.]

MANY writers have claimed that the Northmen encountered the Eskimo in New England nine hundred years ago. At that time, certainly, there seems to have been no permanent Indian occupation of New York and New England, and they may have visited these sometimes, though a Northern people. It is known that they came much farther south than now.

There are analogies between some Iroquois and Eskimo articles yet. The

[1] This conjecture, since this paper was read, has been singularly confirmed. Dr. Franz Boas tells me he has noticed klicks in the speech of the Chinooks and the Western Eskimo. Another informant has heard them among the Mayas; and a Hindoo says that he was greatly surprised at hearing the odd sound produced by klicks in the speech of a dwarf tribe in the Punjaub. — R. G. H.

typical broad spoon is used by both. The quill belt of the Eskimo probably represents the early form of the Iroquois' wampum belt. Their bone harpoons at first were alike. Soapstone vessels were not used by the Iroquois, but shallow soapstone vessels are found along some waters of New York, such as the Eskimo still prize. Half circular knives of slate, like the Eskimo woman's knife, are frequent in New York and Canada, as well as the double-edged pointed slate knife, which is more local.

IROQUOIS MIGRATIONS. By Rev. W. M. BEAUCHAMP, Baldwinsville, N. Y.

[ABSTRACT.]

THERE were three early divisions of the Iroquoian family: the Cherokees, Tuscaroras, and Huron-Iroquois. Though their early route has not been distinctly traced, they made a rendezvous on the upper tributaries of the Ohio, and about the east end of Lake Erie. Many earthworks in Ohio, not assigned to them, seem to have belonged to them. The undisputed ones are of a ruder character than most Iroquois works, but, judging from reports, a group on the Pennsylvania line, in Ashtabula county, is clearly Iroquois. I see no reason to deny the same character to a group of forts in Ashland county, and others might be mentioned even farther south and west. In this I am supported by an expert who has done much field work there. Marked differences of dialects point to early divisions.

The Huron-Iroquois were first encountered by Cartier, in 1535, and those he met were the ancestors of the modern Mohawks, who left Canada for New York late in that century. All traditions agree that they were then feeble, but soon became strong.

A wide district separated the Hurons from the St. Lawrence River, nor is there any evidence that they ever dwelt upon that stream. According to their early accounts, two of their four nations entered Canada early in the fifteenth century, and archæological evidence agrees with this. Another nation came about 1600, and another in 1620. Smaller bodies followed. A third of their village sites were occupied between 1615 and 1650. Allowing for changes and growth, this would agree with their own date. The movement was from south to north.

The Neutrals moved westward from Lake Ontario and the Niagara River, withdrawing their remaining towns from New York in the seventeenth century. The Eries at first dwelt near the southern shore of their lake, but moved inland on account of their enemies, not long before their destruction. They must have held portions of Ohio. The Andastes moved southeasterly from the common home, and of some small nations little is known. Twelve were named in 1635, and more than double that number in 1640.

The Senecas and Cayugas moved eastward, and the ancestors of the Onondagas went to the eastern end of Lake Ontario, probably by water, and apparently in the fifteenth century. Three hundred years ago they sought their later territory.

TRANSLATION INTO PRIMITIVE LANGUAGES. ERRORS AND PITFALLS; WITH ILLUSTRATION FROM ALGONKIAN DIALECTS. By Dr. A. F. CHAMBERLAIN, Clark University, Worcester, Mass.

[ABSTRACT.]

THE author began by considering the significance and etymology of the word "to translate." To *translate*, — *transferre*, *traduire*, *übersetzen*, — is to "carry over," to "set over," an idea more primitively expressed in Aramaic where "to translate" really signifies "to throw a bundle over a river." In the Maya language the priests were termed *chilan*, the "interpreter," literally the "mouth-piece" of the deities; the Aztec *nauatlo*, an "interpreter," is derived from *nauati*, to "speak clearly and distinctly, to explain;" in Chippeway, an "interpreter" is called *anikanotage-winini*, the "repeat-man," and in *itwestamâke-wiyiniw*, the "speak-for-man." Our English word *talk* has, in some of the Letto-Slavonic languages from which it is derived, the meaning "to explain, to interpret." An "interpreter" was probably nothing more originally according to the etymology of the word, than "a broker, a go-between." A *rendering*, a *version*, is no more than a "change" or a "turning," a "giving back." Attention was called to the value of translations of the Bible into primitive tongues as furnishing abundant material for the psychological study of certain aspects of human speech. To translate into the languages of uncivilized peoples such terms as *God*, *Trinity*, *Our Father*, *baptize*, *soul*, *flesh*, etc., is a task hedged round with almost insuperable difficulties. Col. Mallery tells us that "the Choctaw word presented as 'God' for two centuries is now found to mean a *high hill*;" a Mohawk must say either "His Holy Ghost," or "Their Holy Ghost," his language permitting of no ambiguous statement of the procession; the *Kātłōnā'tlā*, "Our Father" of De Smet's Kootenay *Pater Noster*, tells at once that the missionary's collaborator was a man, for a woman must say *Kā'sōnā'tlā*; the ambiguity of the word "to baptize" must disappear before it can be properly rendered in some of our American languages in which "to dip" and "to sprinkle" are not regarded as in any way synonymous. The Algonkian tongues into which so much of the religious literature of the great Christian churches has now been translated, offer many examples of what may be called "translation-words," that is, words changed in meaning or made up by the missionaries. The author gave many instances of such words and expressions from the Chippeway and related dialects.

INCORPORATION IN THE KOOTENAY LANGUAGE. By Dr. A. F. CHAMBERLAIN, Clark University, Worcester, Mass.

[ABSTRACT.]

INCORPORATION and allied morphological phenomena are essential characteristics of American aboriginal tongues, and the consideration of these in the Kootenay of British Columbia, — one of the most recent linguistic stocks to be scientifically investigated, — is of interest to all Americanists and students of language. The Kootenay presents examples of the following varieties.

I. Incorporation of the pronoun-object:

(*a*) n-ū'pqa-nē = he sees; n-ū'pqa-n-*ă'p*-i-nē = he sees *me;* n-ū'pqa-n-*is*-i-nē = he sees *thee;* nū-'pqa-n-*āwa's*-i-nē = he sees *us;* n-ū'pqa-n-*iskĕ'tl*-nē = he sees *you.*

hin-n-ū'pqa-n-*ă'p*-i-nē = *thou* seest *me;* *hin*-n-ū'pqa-n-*āwa's*-i-nē = *thou* seest *us.*

hō-n-ū'pqa-n-*i's*-i-nē = *I* see *thee;* *hō*-n-ū'pqa-n-*is-kĕ'tl*-nē = *I* see *you.* The radical for "to see" is *ūpqa.*

(*b*) i'tqa-nē = he bites; i'tqa-n-*ă'p*-i-nē = he bites *me;* i'tqa-n-*i's*-i-nē = he bites *thee;* tsqātl-i'tqa-n-*āwa's*-i-nē = he is going to bite *us.* The radical for "to bite" is *ùqa.*

hin-ts-ă'mātiktc-*ă'p*-i-nē = *thou* givest *me;* *hō*-ts-ă'mātiktc-*i's*-i-nē = *I* give *thee;* n-ă'mātiktc-*ă'p*-i-nē = he gives *me.* The radical for "to give" is *āmātiktc.*

(*c*) *hi'n*-ts-qātl-ō'tlpātl n-*ă'p*-i-nē = *thou* wilt hear *me.* The radical for "to hear" is *ōtlpātl.*

hō-ts-i'pitl-*i's*-i-nē = *I* kill *thee;* ts-qă'tl-ipitl-*ă'p*-i-nē = he will kill *me;* ts-qă'tl-ipitl-*i's*-i-nē = he will kill *thee;* n-i'pitl-*i's*-i-nē = he kills *thee;* n-i'pitl-*ă'p*-i-nē = he kills *me;* *hō'*-ts-ipitl-*i's*-i-nē = *I* kill *thee.* The radical for "to kill" is *ipitl.*

(*d*) mi'tqa-n-*ă'p*-i-nē = he shoots *me.* "To shoot" is mitqa.

In the examples just given the object-pronouns *āp* (me), *is* (thee), *āwas* (we), *iskĕtl* (you) are found. It is doubtful whether the *n* immediately preceding these syllables belongs to them or is a verbal particle. The pronouns-subject are *kă'min* (I), *ni'nko* (thou), *kă'minăʼtla* (we), *ninkōni'skētl* (ye), from which it will be seen that the object-pronouns for "thee" and "you" alone seem related to the corresponding subject-pronouns. In Kootenay the third persons singular and plural seem to be identical, n-ū'pqa-nē signifying both "he sees" and "they see." The exact form of the inclusive pronoun-object of the third person, if such exist, is not yet known.

II. Incorporation of the noun-object:

(*a*) n-ă'tl-*tlām*-ki'n-ē = he carries the *head* in his hand.

wānk-ō'-*tlām*-ki'n-ē = he shakes the *head* in his hand. The word for "head" is *āqktlām.*

(*b*) hō-ts-tlū'-*tsk-ātl*-qō'nē = I take the *bark* off (a tree). The word for "bark" is *ă'qkitsk-ă'tl.*

(*c*) *sā'-ktūnām*-i's-i-nē = there is a *village.* The word for "village" is *āqktlū'nām.*

hō-tlū'-*tlām*-ă'ɛnē = I deprive of the *head.* The particle *tlū* is privative

(*d*) n-ēk-*ū'*-tl-nē (if = n-ēk-*wū'*-tl-nē = he eats *water*) = he drinks.

(*e*) mā'tl-n-*āk-tlē'tl*-nē = he opens his *eyes.* The word for "eye" is *āqkā'k-tlētl.*

tsū'p-n-*āktlē'tl*-nē = he shuts his *eyes.*

(*f*) hō-tlit-*ka'iyūkwă'*-ɛnē = I have no *hat.* The word for "hat" is *aqkă'iyūkwă'ɛnām.*

hō-tlit-*t'āwū'*-tē = I have no *gun.* The word for "gun" is *t'āwū.*

(*g*) n-ă'wits-*k-a't*-kin-kū'-i-nē = he catches the *tail* in his hand.

qā wi'ts-*k-āt*-ki'n-u! = catch (thou) the *tail* in thy hand. The word for "tail" is *āqk-ă'tɛnām.*

(*h*) witl-*nṓ'kwē*-nē = the *stone* is large. The word for "stone" is *nokwē*.
(*i*) tlit-*k·ā́t*-i-nē = it has no *tail*.
tlū-*k·ā́'iyūkwā*-kin-ḗ'-yām = to take off one's *hat*.
tlū́'-*tlūm*-kin-ḗ'-yām = to take off one's *moccasins*. The word for "moccasins" is *tlūmā*.
tlū-*k·tlānt*-ētl-ēk = throws off his *clothes*. The word for "clothes" is *āqkōk·tlānt*.

III. Incorporation of negative particles:
(1) *k·a*. *k·ā*-i'-nē = it is *not*; hṓ'-*k·ā*-ṓ'pQa-nē = I do *not* see; hō-*k.a'*-wāsQḗ'-mēk = I do *not* sing; hṓ'-*k·ā*-ik-i-nē = I do *not* eat.
(2) *tlit*. tlit-*k·tlētl* = blind (lit. without *eyes*); hō-tlí't-*tāwū'*-tē = I have no *gun*; hō-tlit-*tlūmā'*-i-nē = I have no *moccasins*.
(3) *tlū*. tlā-*tlū'*-nē = there is *no* more.

PRIMITIVE ANTHROPOMETRY AND ITS FOLK-LORE. By Dr. A. F. CHAMBERLAIN, Clark University, Worcester, Mass.

[ABSTRACT.]

THE etymology and original signification of our common English words (and of their cognates and equivalents in other languages), *span, hand, foot, cubit-fathom*, to say nothing of the even more expressive and self-explanatory *finger's-breadth, arm's-length, knee-high, ankle-deep*, etc., go back to the same prehistoric and primitive anthropometry from which the classic nations obtained their canons of proportion and symmetry of the human body; a distinct survival is to be seen in the belief of the peasantry of north-central Europe that the child's face should be as long as the mother's hand.

"Worth his weight in gold" is an expression which has behind it a long history of folk-thought. Ransom by weight, the giving of one's weight in gold or other precious substances to the church as a cure for, or a preventive of disease, or as an act of charity, the *tulâpurusha* of India, are found in many parts of the world, as Gaidoz, Haberlandt, Grimm have shown. Somewhat allied is the practice of offering, under like circumstances, the *image* of a man, the model of one of his limbs, etc., executed in due proportion and weight in some valuable substance. In the Welsh chronicles we find mention of "a staff of silver, as large and as tall as himself, and a plate of gold of the breadth of his face," mentioned as the atonement for insulting a king, and "a golden rod as long as himself, of the thickness of his little finger, and a golden tablet as broad as his face and as thick as a husbandman's nail." The *tulâpurusha*, or "man-weighing" of India is frequently referred to in the historical, legal, and sacerdotal literature of the Hindoos, and has been practised several times within the last few years, — the Maharaja of Trarancore furnishing one of the very latest examples. It is said that it is incumbent upon pilgrims to a certain shrine at Candragutti in Mysore, to make an offering of their weight in "coins, fruit, grains, and other objects of small value."

In the Catholic Church of the Middle Ages somewhat similar practices were in vogue. Henri Estienne, a French writer of the sixteenth century, tells of a monk who bade the parent of a sick child offer up "a wax effigy of his own size," and even poor people were accustomed to wax candles of the height or of the weight of the sick person, wax limbs, wax eyes, etc.

A reasonable explanation of all these practices is that the image of the man, the man's weight, etc., stood in lieu of, was offered to the shrine instead of, the man himself.

That certain rude tests of physical efficiency and bodily strength are in use among primitive peoples, especially at the birth of children, or just before or at the coming on of puberty is a well-known fact, testified to by the frequent occurrence of these practices in fairy and wonder tales. Lifting stones, jumping over obstacles, throwing stones, spears, etc., crawling or creeping through holes, — the last survives even yet in England, — as the test of virginity in certain country districts, as Dyer has pointed out in his "Church Lore Gleanings."

The most systematized primitive anthropometry of which we have any knowledge is the measurement of children previous to circumcision in Madagascar, the details of which are given by Ellis in his history of that island, and the measurement of the neck as a test of puberty (also of virginity) obtaining in Brittany, among the Kabyles of Algeria, and elsewhere, a practice known even to the Roman poet Catullus, and reappearing in the cabalistic magic of the eighteenth century.

THE ORIGIN OF NUMERAL WORDS. By Prof. LEVI L. CONANT, Worcester, Mass.

[ABSTRACT.]

COUNTING, in general, begins with the use of the fingers; and for this reason numeral words are often derived from, and in some instances are identical with the names of fingers themselves. One of the commonest words found imbedded in the various numeral systems of the world, is the word *hand*. The words *foot* and *man*, are also found, but much less frequently. So widespread has finger counting been found to be among savage races, and so commonly do the individuals of civilized communities have recourse to their fingers as an aid in counting, that some authorities, prominent among them Grimm and Pott, have asserted that all numeral words are of digital origin. Investigation shows that this is not the case. Many, and perhaps most numeral words have such an origin, but not all.

The formation of any scale is a very slow process. Numbers are used in a most indefinite way, and for a long time there is no distinct perception of their actual value. Hence precise terms come into use but slowly. In some cases we find more than one form used to describe the same number. Usually but one of these will ultimately survive, though two or more may do so. Among some tribes several different classes of numerals exist, each being used to describe different objects. Ordinals usually have the same form as cardinals, the same word serving for both uses.

The limited capacity for counting manifested by rude, primitive races, leads us back to the time when "1, 2, many," was the entire number scale of sav-

agery. The dual number found in so many languages points to the time when these three were the only numbers in existence, leading severally to the use of the singular, the dual, and the plural numbers. Among primitive races, the greatest variety of numeral formation is given. Examples in detail are given of these in the paper.

SOME INDIAN FISHING-STATIONS UPON LONG ISLAND. By WM. WALLACE TOOKER, Sag Harbor, L. I., N. Y.

[ABSTRACT.]

THIS paper is a study, with interpretations of some Indian names of Fishing-places upon Long Island, N. Y., together with some historical facts relating to the same, gathered from the early records and documents of the 17th century.

[This paper will be printed in the Brooklyn Eagle Almanac for 1895.]

THE DISCOVERY OF CHAUNIS TEMOATAN OF 1586. By WM. WALLACE TOOKER, Sag Harbor, L. I., N. Y.

[ABSTRACT.]

THIS paper is a study of the relation of Ralph Lane of the Roanoke Colony of 1586, and an attempt to identify the province of Chaunis Temoatan, where, as Lane was informed by the Indians, existed a mine of a most "marueilous and strange Minerall," which they called "Wassador or copper," but which, according to the translations of the Algonquian terms therein, was nothing more or less than salt.

[This paper will be printed in the American Antiquarian for Jan. 1895.]

NOTES ON THE CUSTOMS AND TRADITIONS OF THE MIC MACS. By STANSBURY T. HAGER, Brooklyn, N. Y.

[ABSTRACT.]

THE Mic Macs possess a curious system of communicating while in the woods. This consists of notched sticks, which indicate the near presence of some picture writing on birch bark. A popular game amongst them is that called wŏltestĕmkwŏn, a kind of dice of unknown antiquity and evidently pre-European origin. The materials of this game are a circular wooden dish almost exactly a foot in diameter and considerably hollowed, six dice, and 55 counting sticks. The wŏltes or dish is sometimes used for divination. The dice bear a cross design on one side, and are unmarked on the other. They are of caribou bone. The counting sticks are of three kinds. There are 51 plain rounded bars, 3 notched sticks, and 1 king-pin, which generally serves as a 52d plain bar. The count is quite peculiar and complicated. By an ingenious arrangement the sticks can be used to represent an indefinitely large number of points. Clumsy features, however, mingle strangely with this device, and there is some suggestion that these features may have been retained from

some motive other than utility. Odd numbers are conspicuous in the count. Only three even numbers are used. Two notched sticks, placed side by side with the king-pin in front, present an unmistakable arrow. This suggests arrow designs in South and Central America and the magic arrows of the Mic Mac demigod Glooscap.

Another game is turvardigik or foot ball; very rough in former times, when scalping was an element of the play.

Choogichooyajik, or "The Serpent Dance," is a prominent feature of Mic Mac ritual, and presents according to the Mic Mac's own interpretation, an imitation of the rattlesnake awakening from his winter sleep, coming out of his hole, coiling and uncoiling, and shedding his skin. Since there are no rattlesnakes in Nova Scotia or adjacent countries, it seems probable that this dance must have been brought by or to the Mic Macs from the southwest. In Maya, tzabec signifies the Pleiades or rattle asterism, and chuch, the scorpion, is connected with these stars. This group of stars is conspicuous in connection with time relations and ritual dances in America and various other parts of the world, as shown by the researches of Mr. R. G. Haliburton. In Nova Scotia it may possibly have served as an initiation ceremony.

A hitherto unpublished Mic Mac legend is that of the Water Fairies. It relates how a group of beautiful girls playing ball in a cove are observed by a young warrior who, after two reverses, succeeds in capturing one of them. In exchange for her he receives her younger sister for a bride. Next spring the family visit the home of the bride's father beneath the sea. He, the king of fish, is fish below his waist.

Finally, there is the legend of the Culloo and its Victim. The culloo, a winged monster, most terrible of creatures, captures a hunter and carries him off to its nest. But the hunter manages to save his life by a trick, and spends some time in the nest with the little culloos. There is a terrible storm, and then the hunter tries to escape from the nest on the wings of the young culloo which he has slain. The old bird pursues, but fails to capture him. In Maya Kul is the croup of a bird, or the young bird, foreteller of seasons. The legend suggests the Phœnix.[1]

[This paper will be printed in The American Anthropologist.]

LEGENDS OF THE MAGIC WOOING AND THE PIASA. By STANSBURY T. HAGER, Brooklyn, N. Y.

[ABSTRACT.]

KENNEDY relates the Celtic legend of the Golden Pin of Sleep. It is concerned with the quest of a bride. The hero is assisted by a supernatural power which sends three strange characters to his aid. Two of these, Tied Foot and the Blower, are identical in name with two men who perform a like office in a Mic Mac legend related by William Elder, and in that legend there are several other points of similarity with the Mic Mac story.

[1] The author's thanks are due to Maj. W. S. Beebe, for valuable assistance in the preparation of this paper. Also to the two Mic Macs, Abram and Newell Glode.

In another Celtic legend, Kennedy relates the story of the dragon, Piasta or Piastha, who is connected with almost every lake in Ireland. A story agreeing with this in many details is told of the dragon-bird, Piasa (pronounced Piasaw), by the Illini. It is given by McAdams with a description of a cutting of this fabulous monster on a bluff near Alton, Ill.

ANTHROPOLOGIC MATTERS IN MICHIGAN. By HARLAN I. SMITH, Saginaw, E. S., Michigan.

[ABSTRACT.]

ALTHOUGH there has been no extremely marked change during the past year, in the progress of anthropology in Michigan, nevertheless, it is gratifying to notice that the subject is receiving more attention than it has in the past. In some localities the growth of popular interest and intelligence in this study is noticeably on the increase.

Several literary societies in the State have included in their winter programmes courses of study which practically come under the head of anthropology. These studies are especially related to "American Antiquities," "The Native Americans," and "Pre-Columbian America."

The librarians of some of the leading study libraries of the State report that they are continually receiving calls for anthropologic literature, and that the number of persons calling for such literature is on the increase. Many calls are for works not included in the libraries, and, as a consequence, additions are being made to this department, and scientific periodicals which include anthropologic subjects are being added to the subscription lists.

There has been added to the collection of specimens in the Anthropologic Department of the Museum of the University of Michigan, a fine series of objects from the sand mounds of the St. John's River, Florida. These specimens are the gift of Mr. Clarence B. Moore of Philadelphia. Together with his valuable report upon the work which he has conducted in these mounds during the past few years, these specimens form a very interesting accession to the museum.

Under the joint auspices of the Detroit Branch of the Archæological Institute of America and the University of Michigan, the author has been enabled to take up and continue the work of investigating the so-called "Garden Beds" of the State. Thus far particular attention has been paid to those in Kalamazoo County. This work was instituted by the University in 1892. At that time photographs were taken of the surface, and two careful surveys, by expert surveyors, were made of these earthworks on the land of Mr. Charles Price, near Oshtemo, Kalamazoo County. From the data thus obtained a contour map has been made of a set of these earthworks, which were well preserved and protected by the natural timber. From this map, together with the photographs and other data, it will be possible to construct an exact model of these interesting works as they now appear. During this season a survey has been made of the "beds" upon the land of Mr. C. A. Glynn, some three miles distant. The location and size of the oak-trees growing upon the ridges has been noted, and cross sections of the earthworks have been cut and photo-

graphed. Similar earthworks remain yet to be examined in various sections of the State. The report of the work thus far done is to be made direct to the Detroit Branch of the Archæological Institute of America at the close of the year.

These advances in the work of anthropology indicate that on the whole interest in the study is progressing in the State. From the nature of the field, in its original richness, unexplored and peculiar to itself, such an awakening of interest is highly desirable and encouraging. The question of vital importance is, How shall this interest be directed so as to produce the best results, and to avoid the mistakes that have been made in other localities of unintentionally destroying and ignoring valuable evidence? With the present advantages and advancement in methods, the outlook for the future is certainly encouraging.

THE SEAT OF CONSCIOUSNESS. By Dr. PAUL CARUS, P. O. Drawer F., Chicago, Ill.

[ABSTRACT.]

PHYSIOLOGISTS commonly consider the hemispheres as the seat of consciousness. The insufficiency of this theory. Facts pointing to another solution. Unconscious cerebration has its seat in the hemispheres. The consciousness of Professor Goltz's dog, whose hemispheres have been removed. Distinction between feeling and consciousness. The nature of consciousness as a complex state of co-ordinated feelings. Where is the organ of co-ordinating feelings and motor impulses? The physiological nature of the striate body. The striate body a hemispheric ganglion; it belongs ontogenetically to the cortex, not to the midbrain. It is not an internodium, but a terminus in the same sense as the hemispheres. Its function must be co-ordinated with, not subordinated to, the activity of the cortex. Wernëcke's analysis of the fibres in the striate body. Nothnagel's Laufknoten. Landois's view of the function of the striate body. All this points to consider the striate body as the organ of co-ordinating cortical activity.

Conclusion: The unity of consciousness produced by a convergence toward one purpose.

[This paper has been printed in The Journal of Comparative Neurology.]

PRIMITIVE TREPHINING OF PERU. By W J McGEE, Bureau of American Ethnology, Washington, D. C.

[ABSTRACT.]

THE chief purpose of the communication is the exhibition of the Muñiz collection of Peruvian crania, showing primitive trephining, the collection being about to be returned to Lima. Several of the crania were described to direct attention to the features deemed of special interest. The nineteen crania were exhibited.

THE IDEAL MUSEUM. By Prof. THOMAS WILSON, U. S. National Museum, Washington, D. C.

[ABSTRACT.]

THE Ideal Museum building should be adapted in plan and arrangement for light, so to best display its objects. Three grand divisions, in museums, each requiring different treatment — (1) Painting, (2) Sculpture, (3) Archæology, industrial art, and scientific.

Of the first, the light should not be reflected from the object to the eye of the beholder — of the second, it should be just the reverse — of the third, the objects are mostly displayed in cases and under glass, and the light should not be reflected to the eye. Four kinds of opening for light — (1) low windows, (2) high windows, (3) clear-story, and (4) skylights. Four kinds of glass cases for the display of objects — flat topped with horizontal glass, upright perpendicular glass, and two angles of slope-topped cases. All of these may be equally good, but they must be appropriately arranged for suitable light; otherwise they may all be bad.

Arrangements of objects should be such as not to fatigue the senses nor overload the attention. The division of subjects should be such as to have but one main idea presented by one display. There should be much separation of, and distinction in, displays. These should be so arranged as to represent history, science, or culture by epochs or localities.

THE CEREMONIAL YEAR OF THE MAYA CODEX CORTESIANUS. By MARSHALL H. SAVILLE, American Museum of Natural History, New York City.

[ABSTRACT.]

A DISCOVERY of the Tonalamatl or sacred year in the Maya Codex Cortesianus. The Tonalamatl is the Mexican ceremonial year consisting of 260 days. I find a corresponding ceremonial year in the Codex Cortesianus, and a peculiar arrangement of the same which may be of assistance in interpreting the other existing codices.

[To be printed in the American Anthropologist for Oct. 1894.]

A COMPARATIVE STUDY OF THE GRAVEN GLYPHS OF COPAN AND QUIRIGUA. By MARSHALL H. SAVILLE, American Museum of Natural History, New York City.

[ABSTRACT.]

AN identification of the "heading" of the inscriptions of Copan, Quirigua, Palenque, and other Central American ruins, as the Maya month Pax, the sign of which is given by Fray Diego de Landa. This month glyph as a heading is associated with either a vegetal form or in rare instances with a fish. The fish and flower are associated together in the symbolism of the monuments. This

Pax glyph in connection with a frog, an emblem for water, and further with a fish, and with a flower, a fruit, and a hand dropping seeds, establishes the inscription on an idol or tablet with the ceremonies which occurred at the commencement of the rainy season to the god Kukulcan, in order to secure life, prosperity, and an abundant harvest.

The month Pax commenced May 12, which is the time in the tropics when vegetation is dried up, and the most important ceremonies of the year occurred both among the ancient Mexican and Mayas, in order to secure rain. During this month showers foretell the coming of the longed-for rain, and the crops were planted with important ceremonies.

[To be printed with illustrations in Jour. Am. Folk-Lore Society.]

MODERN AND PREHISTORIC VILLAGE SITES IN OHIO COMPARED. By WARREN K. MOOREHEAD, Columbus, Ohio.

[ABSTRACT.]

A SURVEY of several Shawanese and Delaware town sites of 1700-1794 resulted in some interesting discoveries. The character of the ancient and modern sites was compared with care. Pottery and stone implements cover both alike. No expert could distinguish between the ceramics, the stone or bone relics of the two. The modern sites yielded few articles of European manufacture, when we take into consideration that French and English traders were in the towns for more than a century. Lower Chillicothe, which we know was occupied for at least 150 years, has less surface indications than the smallest prehistoric site at Fort Ancient. Thus we can arrive at some basis for comparison of population, time, etc.

THE VALUE OF GAMES IN ETHNOLOGY. By STEWART CULIN, Philadelphia, Pa.

[ABSTRACT.]

THE comparative study of games is one that deserves a high place among our inquiries into the history and development of culture. Their origin belongs to the time preceding that of written records; and many games were not only the product of primitive conditions, but represent the means by which man endeavored to bring himself into communion with and to penetrate the secrets of the natural powers that surrounded him. Thus we find that many early games were sacred and divinatory, and unless we can trace them back to these conditions, we may be sure that we have not obtained the clew to their origin. They have not, like religions, been the object of a propaganda, and yet we find them distributed, comparatively unchanged in form, among the various races of the earth.

The question of their distribution is not less important than that of their origin. How far is their diffusion the result of migration and commerce, and how far that of independent development, the result of similar environment, or, above all, of the practical psychological unity of the entire human race?

The application of these inquiries finds nowhere a more significant field than in America. Among the varied evidence that has been brought forward to support the hypothesis of the Asiatic origin of the ancient Mexican civilization, no one can fail to be impressed with the resemblances between the Mexican game of Patolli and Pachisi, the familiar game of Hindostan. These resemblances — which, as I shall show, amount to identity — led Dr. Edward B. Tylor to regard Patolli as an adaptation of the Asian game, and form the most conclusive evidence, in the opinion of many scholars, that the higher culture of the New World had its source in Asia.

Keeping in mind the fact that games originated before the art of writing, it is not surprising that their origin has been regarded as obscure. They are referred to in the records of China and Japan, and are depicted upon the Egyptian monuments in forms that appear little less perfected than our own games of draughts and chess; and any appeal that we make to history or tradition is answered by a legend like that of Palmedes, or the story that playing cards were made for the amusement of an insane king. With a knowledge of their sacred and divinistic association, we need not concern ourselves with a search for the names of their inventors, or even attempt to fix too closely the age or the people among whom they first appeared. They were the expressions of instincts common to humanity, and their form was a matter of circumstances and necessity. Man has unconsciously recorded his own history, and of these unconscious records I believe that there are none, save language, of greater ethnological value.

Games may be divided, with reference to their origin, into three or four classes, — dramatic, sacred and divinistic, economic, and educational. Many games have existed in several of these classes, and have passed from one to another. Thus the sacred and divinatory games no longer exist as such among civilized races, although the majority of our indoor games, as chess, dice, draughts, dominos, and playing-cards, were derived from them. Suggestions of these early associations, however, survive among us, such as the use of dice and cards in fortune-telling. In Asia, where these amusements are to be found in less sophisticated forms, among races that are lower in culture, we approach nearer the original types, and find the same game existing as a simple amusement, and also performed at stated times for the purposes of divination.

In Korea, a common game of throwing staves, as we throw dice, becomes in the first month the popular method of fortune-telling. This game, which the Koreans call by the to them meaningless name of Ute, I regard as the probable ancestor of all that large family of games which embraces chess, cards, and others I have mentioned. Mr. Cushing has pointed out that the staves were originally arrows. Dr. Brinton has identified the name *Ute*, and its associated terms, with the Tartar numerals; and to this Tartar system of arrow-casting belong half the games of the great continental areas of the Eastern Hemisphere.

The arrows become staves, as in Korea, or little blocks of wood with faces marked in black and white; coins, cowrie shells, knuckle-bones, or a rolling die with notched edges, long dice like the Indian pasa, and cubical dice. In Korea, the casts are recorded upon a circle, around which the players' "horses" go, according to the throws. This circle, by an easy transformation, becomes a cross with four arms, and this, arranged to form a square, the Hindoo chess-board.

Among man's early conceptions was that of the four cardinal-points, the east, the place of the sunrise, and the west, of the sunset. As he stood with his hands outstretched to the east and west, he faced the north or south. A color-symbolism for these directions is almost universal. In the perfected games of Asia we find a four-fold division in which the prevailing color-symbolism of the direction occurs, a survival, it would seem, from the time when the games were sacred, and the players strove, as representatives of the four directions, to decide the gravest questions of fate. The counters, called "horses," which were used by the players in the Korean game, we soon find differentiated by colors, these colors being those of the four directions, which are reunited again in two colors in the Hindoo game of chess.

It will be discovered in the arrow-casting that the opposite faces of the substituted staves, distinguished by the colors white and black, were regarded as symbolizing day and night, light and darkness, the active or masculine and the passive or feminine principles of the universe. Numerical values were attributed to their combinations. With the substitution of the knuckle-bone or rolling die for the staves or blocks, we find this symbolism extended. In China it is still cosmical: "Heaven," "Earth," "Man," and the "Harmony" that united them. In the Mohammedan East, it is sociological: the "Shah," the "Vezir," the "peasant," and the "slave." And here we may discover a clew to the differentiation of the pieces that has taken place in chess; for when it was still a dice game its five principal pieces were moved according to the numerical throws that corresponded with the numbers associated in the knuckle-bones with the four mentioned classes of society.

It was a short step from the knuckle-bone, with numerical equivalents for its throws, to the dotted die. Some time anterior to the twelfth century, the Chinese combined the throws in their favorite game with two cubical dice into twenty-one dominos. These, made successively of bone, wood, and paper, at last furnished the playing card. In tracing the natural history of games, it is interesting to observe the likeness of the existing games of Asia with those described by the Greek and Roman authors. It is clear that many of them had a similar origin; and we come to a realization of the vast intercommunication that must have taken place among mankind before the historic period. We discover, through linguistic evidence, that the Korean game with staves was borrowed from the Tartars; and by the same means we are able to trace the relations of its progeny from the Philippines to Great Britain, from Korea to the heart of Africa.

No stronger evidence of the Asiatic source of much of African culture can be presented than that found in the game of Mancala, the national game of Africa, existing among practically every tribe. It was a game of the Arabs, and has been dispersed with Arab influences from Egypt to the Cape. When we come to America, we find a remarkable correspondence with the games of the Old World. Mr. Tylor has noted that of Patolli; but it is only one among many, and I may add that Patolli not only resembles the Asian game, but it is identical with it, and that this identity is not only one of external form, but of origin and association as well. Mr. Cushing has pointed out that it is the product of sociological conditions which exist naturally in America, and that the game was born and developed in America, just as much else so puzzlingly like the culture of the Old World. Mr. Cushing has found it here in every stage of its

development, not only in Old Mexico, but among practically every tribe on the Northern Continent, and also in the Southern.

Should we accept Mr. Tylor's hasty conclusion that the Mexican Patolli was imported from Asia, we must regard America as practically an extension of Asia. If, on the contrary, we are mindful of the story of its development in the New World, which Mr. Cushing has traced, step by step, always *en rapport* with the prevailing mythic conceptions and stage of culture, we discover only additional confirmation in its correspondence of that great truth to which all investigation seems to lead, namely, the psychological unity of man. Light is thrown by his narrative upon the protohistoric period of the Old World, of which we find a reminiscence in the sacred record, where Ezekiel relates that the King of Babylon stood with his divining arrows at the "parting of the ways."

KOREAN CHILDREN'S GAMES. By STEWART CULIN, Philadelphia, Pa.

[ABSTRACT.]

AN account of the games of children in Korea, with comparisons with the corresponding games in China and Japan.

[To be printed in full in the Journal of American Folk-Lore.]

CRANIA FROM THE NECROPOLIS OF ANCON, PERU. By GEO. A. DORSEY, Ph.D., Peabody Museum, Cambridge, Mass.

THE crania used in the preparation of this paper were collected by me at Ancon, in 1892, while I was in Peru on a joint expedition directed by Professor Putnam for the Peabody Museum and the Department of Ethnology, World's Columbian Exposition.

The methods used in the measurements presented are, in general, based on those of Topinard; while the measurements themselves are confined to those made use of by the Department of Anthropology of the Columbian Exposition.

In taking the measurements the following method was observed: the maximum length was taken from the glabella to the posterior extremity; height from basion to bregma; breadth of base from the centre of one mastoid process to the other; height of face A from the nasal point to the alveolar point; height of face B from nasal point to lower border of the mental process; breadth of face, the maximum diameter between the zygomatic arches; breadth of palate A, the maximum diameter between the points of insertion of the canine teeth; breadth of palate B, the maximum diameter between the points of insertion of the third molars. All other measurements were taken as usual.

In all, 123 crania have been measured, and tabulated in eleven tables. In the first five tables the crania of the males and females have been divided into two groups, — the natural and the deformed. As will be seen, the proportions are not in accordance with those usually given for Ancon. As the original shape of the crania seems to have been of the rounded type, and as the artificial

deformation only tended to increase this character, it has been my practice to consider the cranium as natural, unless the marks of depression are plainly visible. After a careful examination and study of the crania, and method of head-dress used at Ancon, I am inclined to believe that the artificial depressions and flattening were due to the mere accident of a peculiar form of dress, rather than to any desire to produce an artificially shaped head. Furthermore, this custom of wearing bandages around the head seems to have died out; as those crania having the greatest deformation are invariably found in graves which show evidence of great antiquity. Naturally, fillets bound laterally around the head, such as we know were worn, would have a tendency to shorten the head, especially in the frontal and occipital regions. This, we find, was the actual result, the greatest depression being generally at the occiput. Moreover, in only three instances is there any indication that the head of the child had been bound to some hard substance, such as a cradle-board. There the flattening is very obvious, and presents an appearance similar to many of the cradle-board flat-head crania of North America.

In determining the sex, the methods usually adopted from Broca and Topinard have been followed. But in a great majority of crania it was not necessary to resort to an examination; a glance at the objects accompanying the mummy-pack sufficed to indicate the sex. Thus, as one method supplemented the other, it is thought that the collection is of unusual value. In Chicago, I made a special study of the two sexes, noting the physical characters which tended to prove or disprove the supposed sex, as derived from the material objects. In this study Dr. Allen called my attention to the fact that in the male crania the sheath which surrounds the styloid process is more highly developed, and more nearly forms an encircling case. This is a point in the determination of sex worthy of further study.

Cranial Capacity. — The capacity was taken with the same instruments which have been in use in the Peabody Museum since the time of Professor Wyman. The material used was mustard-seed.

Referring to Table XI., we find the average capacity of the entire number of crania to be 1345 cc. The average of the males is 1465 cc., while that of the females is only 1185 cc. The highest capacity is that of a deformed male, 1540 cc.; the lowest is that of a deformed female, 1100 cc.

Further examination of this table reveals the curious fact that the average capacity of the deformed males, 1480 cc., is greater than that of the natural males, 1450 cc.; while that of the deformed females, 1185 cc., is much less than that of the natural females, 1270 cc.

Males. — Of the 58 crania of males, 26 were considered natural, and 32 deformed. The natural crania are rather symmetrical, rough, somewhat heavy, and either rounded or ovoid. The face is short and broad, the average length of the bizygomatic diameter, 138, being greater than that given by Topinard for the Eskimo. On the other hand, the minimum breadth of the forehead is correspondingly low. As will be seen from Table VI., 25 of the crania are brachycephalic, and one mesaticephalic. Even these figures do not convey a true impression, as a considerable percentage were above the limit usually assigned to the brachycephalic group. Over 50 per cent are leptorhinian, 7 are mesorhinian, and 4 platyrhinian (Table VII.). The average nasal

index is 46, being the same as that given by Topinard for modern Parisians and French Basques.

The indices for the orbit are about equally divided among the megaseme, mesoseme, and microseme. The average index is 80. (Table VIII.)

In Table X. are shown the conditions of the sutures. The metopic suture is open in one specimen. The following shows the number of cases where certain sutures have become synostosed: sagittal, 4; coronal, 8; lambdoidal, 1; right parieto-mastoid, 1. In three specimens the sutures are all open, while the aveolar process is more or less absorbed. In only one case does the temporal join the frontal bone; in the other specimens it is separated by an average distance of 11 mm. In general, it may be stated that the sutures are exceedingly simple. In four specimens there is an exostosis in the external auditory meatus; and in one there is a third condoyle at basion.

In Table IX. are shown the results of observations on the prevalence of Wormian bones. It will be noticed that the number of crania is given in each instance which have Wormian bones, and just after it, and separated by a dash, the aggregate number. Thus, in eight specimens there were present 18 Wormian bones in the right lambdoidal suture, and 14 in the left; in three specimens, 8 Wormian bones at lambda; in one, 1 os triquitum; in two, 2 at asterion; and in three, 8 at pterion.

Thirty-two male crania were considered deformed. The principal result of the bandaging of the head was threefold, — a flattening of the frontal and occipital regions, causing a corresponding bulging of the posterior parietals. As a result, the cranium often presents a triangular or three-lobed appearance. Frequently one of the posterior lobes is much more highly developed than the other, and the result is a very unsymmetrical crooked form.

The other differences between the natural and deformed crania of the males may be summed up as follows: (1) A more decided shortening of the crania, resulting in an average cephalic index of 92, with a maximum index of 106; (2) a greater percentage of leptorhinians and mesorhinians, and a corresponding decrease of platyrhinians; (3) no change in the orbital index, although a decrease in the size of the orbit; (4) a decrease in the measurements of the entire face, including breadth of forehead, height, and breadth of face, length and breadth of palate, and (5) breadth of base of the calvarium. There seems to be no perceptible difference in the character or amount of synostosis of the sutures, nor in the number or size of the Wormian bones. Two of the deformed specimens, however, had a third condyle at basion.

Female crania. — The relative percentage of the natural to the deformed crania of females differs slightly from that of males, there being 28 natural and 23 deformed. The general characters of the female crania are their lightness and smoothness, very slight glabella, and sharp, thin, supra-orbital ridge. Almost all of the measurements are smaller than the corresponding ones of the male. This is especially true in the length, breadth, and breadth of base of the calvarium, and the breadth of forehead, and length and breadth of nose, orbit, and palate.

As compared with the male crania an equally large percentage of the female crania are brachycephalic. The nasal index shows a greater tendency toward the leptorhinian nose, and the orbital index a slightly greater tendency toward

the megaseme orbit. There is no appreciable difference in the condition of the sutures or the number of Wormian bones.

In comparing the natural and deformed female crania, the following differences are noticeable: there is not such a marked tendency in the deformed crania toward the extreme brachycephalic type as was found in the two different classes of males, but a nearer approach in the natural crania toward the leptorhinian nose, and a greater tendency among the deformed toward a megaseme orbit. As with the male crania, there is no noteworthy difference in regard to the condition of the sutures or number of Wormian bones, except that in five natural specimens there were eight Wormian bones in the parieto-mastoid suture. Among the natural specimens, there were two with exostosis of the external auditory meatus; two, with a point of articulation for the second vertebra; four possessed open sutures, with an absorbed alveolar process; and in one, the middle nasal suture was synostosed.

Children. — Fourteen crania of children were measured. For obvious reasons, no attempt was made to distinguish the natural from the deformed. Thirteen were brachycephalic, and one mesaticephalic, with an average cephalic index of 85. According to the nasal indices, they are about equally distributed among the leptorhines, mesorhines, and platyrhines. On the other hand, as we might expect to find, the orbital index shows a decided tendency toward the megaseme type, only three being mesoseme, and none microseme.

Conclusions. — To sum up briefly, then, the prominent features of the entire number of crania, we find the following results: Cranial capacity, small; calvarium, decidedly rounded or brachycephalic; nasal skeleton, moderate or mesorhinian; orbit, rounded or megaseme; palate, short and broad; face, short and broad, with high cheek bones; sutures, simple and early synostosed; os Inca, present in only two cases, but Wormian bones exceedingly numerous and complicated.

TABLE I.

Twenty-six Crania. Males (Natural).

	Length-Breadth Index.	Length-Height Index.	Nasal Index.	Orbital Index.	Palate A. Index.	Length.	Breadth.	Height.	Breadth Forehead.	Breadth Base.	Height Face A.	Height Face B.	Breadth Face.	Height Nose.	Breadth Nose.	Height Orbit.	Breadth Orbit.	Length Palate.	Breadth Palate A.	Breadth Palate B.
Maximum	99	85	59	97	74	180	159	140	107	116	127	80	148	58	29	41	47	63	39	56
Average	84	78	46	80	64	168	149	132	95	105	117	71	138	53	24	36	43	55	36	48
Minimum	75	73	37	74	54	156	140	124	84	98	100	62	131	47	20	31	37	49	31	39
Range	24	12	22	23	20	24	19	16	23	18	27	18	17	11	9	10	10	14	8	17

TABLE II.

Thirty-two Crania. Males (Deformed).

	Length-Breadth Index.	Length-Height Index.	Nasal Index.	Orbital Index.	Palate A. Index.	Length.	Breadth.	Height.	Breadth Forehead.	Breadth Base.	Height Face A.	Height Face B.	Breadth Face.	Height Nose.	Breadth Nose.	Height Orbit.	Breadth Orbit.	Length Palate.	Breadth Palate A.	Breadth Palate B.
Maximum	106	88	54	98	72	174	157	137	102	109	112	69	146	53	31	39	46	60	39	45
Average	92	79	47	85	66	165	148	126	96	104	108	66	139	50	25	36	43	55	36	43
Minimum	90	78	45	70	64	156	144	107	87	100	105	65	133	48	21	35	40	51	34	41
Range	16	10	9	28	8	18	13	30	15	9	7	4	13	5	10	4	6	9	5	4

TABLE III.

Twenty-eight Crania. Females (Natural).

	Length-Breadth Index.	Length-Height Index.	Nasal Index.	Orbital Index.	Palate A. Index.	Length.	Breadth.	Height.	Breadth Forehead.	Breadth Base.	Height Face A.	Height Face B.	Breadth Face.	Height Nose.	Breadth Nose.	Height Orbit.	Breadth Orbit.	Length Palate.	Breadth Palate A.	Breadth Palate B.
Maximum	97	90	60	100	72	171	152	140	100	111	117	71	141	54	26	39	44	59	42	46
Average	86	78	50	87	64	161	144	127	92	102	108	66	128	49	23	35	39	53	35	41
Minimum	72	71	42	80	55	150	125	121	85	94	92	52	108	41	18	31	35	42	29	35
Range	25	19	18	20	17	21	27	19	15	17	25	19	33	13	8	8	9	17	13	11

TABLE IV.

Twenty-three Crania. Females (Deformed).

	Length-Breadth Index.	Length-Height Index.	Nasal Index.	Orbital Palate.	Palate A. Index.	Length.	Breadth.	Height.	Breadth Forehead.	Breadth Base.	Height Face A.	Height Face B.	Breadth Face.	Height Nose.	Breadth Nose.	Height Orbit.	Breadth Orbit.	Length Palate.	Breadth Palate A.	Breadth Palate B.
Maximum	101	85	56	99	76	168	161	136	96	107	111	70	135	53	25	38	40	56	39	45
Average	91	80	46	94	70	161	148	129	92	103	108	66	130	52	23	36	38	53	38	39
Minimum	78	72	41	90	62	151	134	123	86	101	105	64	126	47	21	34	37	50	35	38
Range	23	13	15	9	14	17	27	13	10	6	6	6	9	6	4	4	3	6	4	7

TABLE V.

Fourteen Crania. Children.

	Length-Breadth Index.	Length-Height Index.	Nasal Index.	Orbital Index.	Palate A. Index.	Length.	Breadth.	Height.	Breadth Forehead.	Breadth Base.	Height Face A.	Height Face B.	Breadth Face.	Height Nose.	Breadth Nose.	Height Orbit.	Breadth Orbit.	Length Palate.	Breadth Palate A.	Breadth Palate B.
Maximum	90	84	60	99	75	165	158	126	98	101	103	94	122	49	22	36	38	50	38	40
Average	85	76	51	92	72	157	143	124	91	95	101	65	110	40	21	33	35	42	30	37
Minimum	78	70	40	86	69	153	134	120	85	84	98		95	33	19	29	31	36	27	35
Range	12	14	20	13	6	12	24	6	13	17	5	44	27	16	3	7	7	14	6	5

TABLE VI.

Cephalic Index.

	Males.		Females.		Children.
	Nat.	Def.	Nat.	Def.	
Delichocephalic	..	..	..	..	..
Mesaticephalic	1	1	1	4	1
Brachycephalic	25	32	27	19	13

TABLE VII.

Nasal Index.

	Males.		Females.		Children.
	Nat.	Def.	Nat.	Def.	
Leptorhine	14	19	15	11	4
Mesorhine	7	12	6	10	8
Platyrhine	4	1	4	2	4

TABLE VIII.

Orbital Index.

	Males.		Females.		Children.
	Nat.	Def.	Nat.	Def.	
Megaseme	8	10	12	14	12
Mesoseme	9	12	9	7	8
Microseme	9	10	6	8	..

TABLE IX.

Wormian Bones.

	Lambdoidal Suture.		Lambda.	Os Triquitum.	Os Quadratum.	Os Incæ.	Asterion.	Obelion.	Pterion.	Stephanion.	Tempero-Mastoid.	Parieto-Mastoid.	Inter-Parietal.
	Right.	Left.											
Males Nat.	8– 18	8– 14	3– 3	1– 1	..	..	2–2	..	3–3	..	..	..	..
Males Def.	12– 41	12– 29	2– 2	3– 3	..	1–1	..	..	..	1–1	..	1– 2	..
Females Nat.	9– 13	10– 15	1– 1	6– 6	..	..	3–3	..	3–5	..	..	5– 8	..
Females Def.	11– 34	8– 30	1– 1	1– 1	..	..	3–4	1–1	..	2–3	..	..	1–1
Children . .	5– 13	7– 15	2– 2	1– 1	1–1	1–1	..	..	..	1–1	1–1	..	..
Total . .	49–119	45–103	9–10	10–12	1–1	2–2	8–9	1–1	6–8	4–5	1–1	9–10	1–1

TABLE X.

Synostosis of Sutures.

		Metopic (Open).	Sagittal.	Coronal.	Lambdoidal.	Parieto-Mastoid.		Middle Nasal.	Sutures Open and Alveolar Process Absorbed.
						Right.	Left.		
Males	Nat.	1	4	3	1	1	..	..	3
	Def.	0	6	4	0	..	1	..	2
Females	Nat.	1	5	2	1	..	..	1	4
	Def.	2	7	4	3	..	..	..	..

TABLE XI.

Cranial Capacity.

		Maximum.	Average.	Minimum.	Range.
Males	Nat.	1510	1450	1400	110
	Def.	1540	1480	1460	80
Females	Nat.	1340	1270	1200	140
	Def.	1275	1185	1100	175
Total average			1345		

ON THE HISTORY OF THE MEANDER PATTERN, AND ITS CONNECTION WITH THE SWASTIKA. By Prof. WM. A. GOODYEAR, 222 East 69th Street, New York City.
[This paper will be printed in the Architectural Record.]

ARMOR OF THE NORTH AMERICAN ABORIGINES. By WALTER HOUGH, U. S. Natl. Museum, Washington, D. C.
[To be printed in the Report of the National Museum for 1893.]

EVIDENCES OF ABORIGINES IN NICARAGUA. By J. CRAWFORD, Managua, Nic.

SHELL-MOUNDS IN NICARAGUA. By J. CRAWFORD, Managua, Nic.

KITCHEN-MIDDENS OF ROCK RIVER, ILLINOIS. By Dr. A. S. TIFFANY, Davenport, Iowa. (Map distributed.)

IMPROVED TESTS FOR THE DETERMINATION OF VISUAL ACUTENESS IN RAILWAY EMPLOYEES. By Dr. CHARLES A. OLIVER, 1507 Locust Street, Philadelphia, Pa.

AN ILLINOIS DRIFT IMPLEMENT. By Dr. J. F. SNYDER, Virginia, Cass Co., Ill.
[To be printed in The Archæologist.]

BRIEF REMARKS UPON AN ATTEMPT TO INTERPRET PLATES 25 AND 40 OF THE DRESDEN CODEX. By Dr. H. T. CRESSON, Philadelphia, Pa.

LIGHT FROM RECENT SCIENCE UPON MAN'S RELIGIOUS BELIEF. By Rev. GEO. V. REICHEL, Brockport, N. Y.
[To be printed in the Homiletic Review.]

MEXICAN COOKING AND MEXICAN FOODS. By JOHN G. BOURKE, Capt. 3d Cav. U. S. A., Washington, D. C.
[To be printed in Scribner's Magazine.]

THE VALLEY OF THE YUCAY, OR "THE GARDEN OF THE INCAS." By GEO. A. DORSEY, Ph.D., Peabody Museum, Cambridge, Mass.

EXHIBITION OF AN ANCIENT MEXICAN MANUSCRIPT ON MAGUEY PAPER. By MARSHALL H. SAVILLE, Amer. Mus. of Nat. History, New York City.

SECTION I.

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ADDRESS

BY

HENRY FARQUHAR.

VICE PRESIDENT, SECTION I.

A STABLE MONETARY STANDARD.

It is doubtless true that the progress of opinion, on the important practical questions which lead to political divisions, has not been greatly influenced by scientific research or the guidance of scientific men. The substantial triumphs of politics, in the carrying of national elections, or the forcing of contested measures through the many resistances offered by the legislative apparatus, are generally achieved by forces quite different from those which discover and establish scientific truth. Like the successful commander in aggressive warfare, who carries a coveted position by the impetus of an irresistible force hurled against it, the skilled political leader seeks to sway a mass of voters or of legislators by bringing to bear upon it a mighty wave of popular feeling; and, in comparison with emotional fervor, the most effective stimulus to action, sets little store by carefully weighed judgment, the most effective restraint on hasty action, an agent far less fitted to serve his purpose. The faithful votary of science trusts all to judgment and nothing to emotion; he controls no force which can roll up majorities; he is therefore left out of account as a factor in political movements.

Yet despite these facts, or rather in large measure because of them, there are no questions more loudly crying for the brightest light which the purest science can throw upon them, than these very questions of practical politics. Not that the working of political machinery, by any such methods as now control that machinery, should be in the hands of people of scientific training, or

that—in plain English—there is need of a corps of scientific bosses; for, put in a position where success is the highest acknowledged good, the man of science will only seek the same success that others seek, and avail himself of the same tactics. Indeed, it must be confessed that scientific training and an extended knowledge of scientific truth may fail miserably in leading to a truly scientific method of treating questions in which the interest is emotional. Men of science are tempted in all points as other men, and sometimes yield. Rhetorically, a sweeping generality or dogmatic assertion is usually more effective than the best guarded conclusion from carefully sifted data, and even a scientific man may sometimes condescend to the use of it. The contribution which science can make, and ought to make, to politics is by a contrast of objects, not by a rival pursuit of the same objects; by a loyal adherence to methods which lead to the establishment of truth, in opposition to all methods of merely acquiring control of affairs through victories at the polls; by being unfalteringly faithful to itself. While, therefore, it is highly desirable that science should fearlessly meet and (where possible) resolve political questions, it is essential that this be not done as politicians do it; that arguments addressed to prejudices and private or party interests be banished; that justice be done to every morsel of truth, from whatever school or faction it is brought forth; that no conclusion be taught as orthodox doctrine till it has been stoutly buttressed by impregnable premisses.

If any political question has an especial claim upon the attention of a scientific association, or especially needs the application to it of scientific principles, it is that of the monetary standard, one of those inevitably arising from the possession by the national government of the power of legalizing a tender for debts. It hardly needs to be pointed out that if this power, as to which the federal constitution is silent except in the clause where its exercise by individual states is restricted, and whose use by the general government is justified only as an indirect inference from the powers granted, to regulate the value of coins and to raise money on the credit of the United States,—if this power of legal tender did not exist, the question of the monetary standard would settle itself. No legal standard governs the dealings of independent countries with one another; and if the government assumed no right of declaring a legal tender in private commercial transactions, such transactions would rest upon the same basis. The standard of

payment for any contract involving money would be found expressed or implied in the contract itself, and legislation would have nothing to do with the matter, except so far as it is within recognized legislative power to enforce or to impair the obligation of contracts. Legal control over the standard of values or payments must be based on the assumption that private contracts may raise a question which they may not satisfactorily settle—or, to state it more exactly, that what was recognized as money when a contract was made is not necessarily suitable to be recognized as money when the contract comes to be fulfilled, so that the suitable something must be declared by the law-making power. This assumption, whatever may be thought of its merits, has come to be accepted as a part of our inherited scheme of government, and the practical question is, how best to proceed under it.

That stability in value is the essential requisite of the monetary standard, seems incontestable. But what shall constitute stability? Since the word means ability to resist disturbing forces, and since the ability to resist depends on the nature of disturbing force, what kind of force does it most concern us to resist? Value itself, too, is essentially a relative quality, which a thing has not independently, but only with reference to something else; and what is that something with reference to which the standard of values should be stable? Neither of these questions should be neglected in a complete consideration of the subject.

The disturbing forces which the value of the monetary standard ought to have ability to resist, are those which interfere with its function as money. Taking up the uses with which money has been credited, and inquiring what interferences with those uses are to be avoided, we have no difficulty in deciding (1) that as a medium of exchange, it is sufficient if a stability of value is maintained until the exchange is completed, so that the only fluctuations we have to fear are the violent ones which derange prices during the short interval between our sales and our purchases, the more gradual changes, extending over years or even over months, being practically indifferent; (2) that as a common denominator or measure of value, it is the rapid and not the gradual changes that prove real obstacles to the money function, for to the latter the mind can accustom itself, practically, as well as to perfect constancy—particularly in view of the fact that subjective values, the uses which the same objects have for us, in course of our own growth and ma-

turity and senescence, themselves change far more widely than the money metals have ever changed; (3) that as a standard for deferred payments, the constancy required is for the period, longer or shorter, between the time when the payment is promised, and the time when it is made; (4) that as a store or hoard or convenient form of dormant capital, money should hold a constant value for the time—usually short—during which it remains stored. With all uses of money except the third, therefore, slow changes in value, requiring years to become perceptible, do not injuriously interfere, and need hardly be considered. With regard to its use as a standard for deferred payments, any changes in its value, not contemplated by the contracting parties, must of course be injurious to one of them and unfairly favorable to the other, whether the change be slow or speedy. But the case is different with gradual changes, in process when the contract is made. Any factor which is to affect the value of an anticipated payment is naturally taken into account in estimating the present worth of that payment. Adjustments of this kind are made in fixing the rate of interest, which is necessarily higher when the unit of value is depreciating, and lower when it is relatively increasing, since interest is, as precisely as the word can be defined, the difference between the value of present money and the present value of future money. The general conclusion is that for all purposes except that of discharging a very small proportion of the obligations in force (a proportion which, it ought in justice to be admitted, is not quite so small in respect to total amount as in respect to number, for some of those obligations are for large sums), a gradual change in the monetary unit is of slight importance, and the only serious changes are the short, sharp, sudden ones. Stability is here like seaworthiness in the ship, of which very little is required to ride the slow tidal waves, and hardly more to withstand the great swells, but which is called into full exercise in bearing up against the chopping sea. Our unit of value should steadily ride the chopping seas of ebbing and flowing commerce.

The direction in which these disturbing forces act is a question of some importance, and is thought to have more importance than it has. Is there a foundation for the doctrine so zealously taught, that a change in one direction is hurtful or dangerous, and a change in the other harmless or even salutary? It is quite true that more complaint has been made of falling prices and appreciating cur-

rency, said and believed to be scarcer, than of advancing prices and baser currency, credited with being plentier and "easier"—or at least that the former kind of complaint is always favored with a louder popular echo—because the debtor has readier access to the sympathy of his fellows than the creditor can ever hope for; but what reason can be given in its support, apart from the appeal to prevalent partiality? The public interest, we are reminded, is more with the debtor because social progress is largely due to his hopefulness and enterprise. We are even told that "a market that is constantly falling as a result of an appreciating currency" . . . . "is perhaps the most deadening and benumbing influence that can touch the enterprise of a nation." Capital is discouraged from production of goods whose price is falling, drawn out of businesses in which the community is served and into idle hoarding. Nor is this the final clause in the chapter of ills, for in a growing scarcity of money we are to read the doom of civilization itself; the good old Tory historian Alison being drawn upon for sonorous demonstrations that the night of the Dark Ages, following the fall of the Western Empire, was brought about by a failure of the money supply, and that the modern revival of culture is a direct outcome of the quickening of Europe by silver from Potosi. The list of arguments of opposite tendency, favoring appreciating money and the creditor's side, is very much shorter. The most important of them is the interest of the laboring man, which is unquestionably, though too many people fail to realize it, altogether that of the creditor. "The creditor class," so often portrayed in appeals to imaginative sympathy, is made up of corpulent capitalists, clipping coupons in lazy luxury, swarming the multifarious pleasure resorts along the Atlantic coast, whenever not in prosecution of its unblessed machinations in Wall Street—the creditor class of sober fact includes as its most numerous and practically most important element, the scores of thousands of manual laborers whose wages are in arrears—toiling men and women whose compensation has been postponed, or who voluntarily leave funds in the hands of their employers because believing them safest there. To this briefer showing of arguments the reply may be in like manner briefer: it is enough to say that arrears of wages, though the amount of them may reach a huge figure in the aggregate, are rarely large in any individual instance; and that the times for which they remain due are measured usually by fractions of a month, rarely prolonged to many months, so that

the suffering that would be caused in any case by a depreciating unit of value must be, unless the depreciation were violent, inconsiderable. To advocate an appreciating unit of value as a measure of deliberate policy, for the sake of the advantage that would accrue from it to the great body of wage-earners, would be, moreover, practically futile. Any movement of this kind, by which the working man could be benefited, would infallibly be discounted to his disadvantage beforehand, by the same management that great manufacturing firms now use, when they cut off the profits which more economical applications of machinery would otherwise bring to their piece-workmen, through successive reductions of their rate of compensation per piece. We may depend upon it, the first benefits of social changes of any kind are going to come always to those most and not to those least able to foresee them.

But how about the supposed reasons for preferring a currency whose value is gradually sinking? The advocates of such a currency do not usually, it is true, lay stress so much on the depreciation as on the greater abundance of the material forming the measure of values. This is what they delight in calling a stimulus, and its effects are indeed analogous to those of the stimulus physiological. It gives not strength, but a feeling of strength; it brings out energy for present expenditure by drafts on the reserve, which drafts must some time be met in full without default; it may be very useful in tiding over a season of low vitality, but is reckless folly when there is no abnormal demand to be met. Very little attention need be paid to the instances from history, adduced to prove a high civilization the result of an abundant gold and silver supply, simply because in this supposed proof, like so many others which the economical inquirer is called on to examine, the relation of cause and effect is reversed. It is indubitably true that a higher stage of civilization will bring to light and find use for more of the precious metals than will a lower, and in that truth we have all the explanation we need for the coincidences exploited by Alison. The question of business enterprise may be treated with somewhat more gravity; for enterprise is a blessing not to be decried, still less to be sacrificed, or even needlessly endangered. But so far as this blessing depends on the reward awaiting it, we must admit that a gradually depreciating currency will not certainly insure it if the depreciation can be foreseen and allowed for; since the fact is well established that interest is higher on a depreciating and lower on an

appreciating capital, so that the enterpriser must pay out in that way what he makes in the other. Then how far is it true that a moderate tendency to depreciate will have the effect of keeping capital active that would otherwise be hoarded, thus providing more work for willing hands and more efficiently serving the community? This is an argument of high plausibility; in fact it might even be admitted to have a considerable share of truth in it, but that it fails to take proper account of the real causes and conditions of hoarding money, for is it not a fact of experience that money is kept idle, rather from a fear of losing it altogether than because the return from its investment is thought too low? We all know that investments believed to be unimpeachably safe, such as the bonds of a solvent government, never fail to draw out money that remains hidden from others of far fairer promise but of less security. Can there be any doubt that the tendency appealed to in this very argument, the attraction of money to better-paying investments, would be effective in drawing it to even a low-paying enterprise in preference to no interest at all, if entire safety were assured? Otherwise expressed: "The greatest part of the evil of a diminishing money supply is wrought through the discouragement of enterprise, through the diminution of legitimate profits, through the preference given to all investments of capital which result in a fixed charge upon production, over those which involve a participation in the gains or losses of active business." This sentence is quoted from one of the ablest and most celebrated economic writers our country has produced, but even the respect commanded by his name, standing and work are insufficient to give it practical justification. The returns of investments resulting in a fixed charge on production depend inseparably on the returns of the production, and must necessarily rise or fall with them. The law of demand and supply suffices to prevent too attractive investments from becoming disproportionally profitable. As a matter of observation, business enterprise is subject like "animal spirits" to ebbs and floods, all uninfluenced by the state of the currency—or rather, indeed, moulding for itself a currency in accordance with its own unrestrained caprices—and the stronger the floods the lower will be the ebbs. Each in its own way, our sad collapses of 1837 and 1857 and 1873 are all traceable to over-stimulated business enterprise, and warn us unmistakably that even so good a thing can sometimes be redundant. It may well be doubted whether an avowed and deliberate

encouragement of debtors as a class, is good policy, notwithstanding their enterprise and their progressiveness. The objection that too much encouragement may make them too enterprising and too progressive, is no less well-founded than obvious; but a more serious objection arises from inquiry at whose expense the encouragement must be had — what important section of the creditor class there is, gifted with neither the power nor the skill nor the knowledge to escape the consequences of money depreciation. Plainly the laborer must bear the expense of it, because he alone is unable to contrive to avoid it. The capitalist can refuse to lend, or to extend loans, except at higher interest; the working man must enter the market with his only merchandise, the toil of his hands, which must be disposed of for what it will bring, at once, or else be lost. The necessity that the laborer must suffer in his earnings when money depreciates is all but self-evident The fact that he does suffer is clearly proved by Mr. Atkinson's investigations, to be laid before the Section at this meeting, and can also be read from the accompanying chart, where values in war-time are reduced from paper to specie. Finally, the difference does not seem to be vitally important, whether a currency depreciates as a direct result of its greater abundance, or from any other cause whatsoever. An increased abundance to which the limits have become evident, as from the opening of mines whose production has begun to fall off, is less hurtful as a source of depreciation than one to which no one knows where to set a limit; but the difference is of quantity rather than quality. The value of money could be destroyed as hopelessly, and essentially in the same way, by unlimited increase in quantity as by unlimited debasement in composition.

This assumption, that the good of society might be advanced by money growing cheaper, has called for a much more elaborate refutation than the rival assumption that benefit is to be had from money growing dearer. The reason is merely that the one assumption is more frequently made than the other; not that there is any essential difference in point of demerit between the two. Whether it be appreciation or depreciation, every change in the standard by which values are reckoned is more hurtful than helpful, and the chief consideration determining the degree of hurtfulness is that it is greater the more sudden, and less the more gradual the change. But the important question, what is to constitute a change, and how we are to estimate the degree of it, or even the existence of

it, yet remains unanswered. It need hardly be confessed that if we are without means of satisfying ourselves whether a change has occurred, or what kind of a change it is that has occurred, the discussion of this subject must be lacking in practical interest.

A change in value, like change of every kind, is unmeaning except in relation to something which is understood not to change. What, in the case of values, is or ought to be that something? This is a question to which we give a practical answer every day, in terms of our customary currency. Precisely the same inquiry, over which we are puzzling our heads this afternoon, is in the same hour receiving its hundred thousand answers, wherever a commercial transaction is conducted or any estimate of worth or price made. And are those hundred thousand answers as satisfactory as the best answers to which our closest reflection can lead us? In all but a small minority of cases, yes. In all but a very few of that minority—perhaps a few dozen out of the hundred thousand—the answer, in terms of customary currency, is seriously unsatisfactory only when the fluctuations of that currency are abrupt and violent. But of course the true measure for which we are seeking ought to suffice for these few exceptional cases also, as well as the great mass of cases for which any accepted measure suffices. Thus there was a decided contradiction in our estimates of the natural unit of value, in the war and reconstruction days when there were widest changes in the factor that we knew as "the price of gold." As this price rose or fell, other prices rose or fell with it, and this had in many ways the effect of a real movement in values, for people acted and felt, when the currency price was higher, as though they were receiving a larger return for their merchandise; and when it fell off, as though they suffered a real loss. But for those who dealt with other countries where there were no such fluctuations, there was no such reality. Among the more reflecting of our people, even without the evidence of foreign trade to remind them, there was all the time a sense that values were not changing as prices changed; and yet, so strong is the tendency to look upon the nominal unit as a true unit, few of us who have had anything to do with statistical investigations can have failed to see more than one interesting and promising inquiry, dealing with values, sadly vitiated by a naïve use of the census figures for 1870 as if the "dollars" in its tables had the same meaning as those for 1860 and 1880, and as if any conclusions

worth considering could be reached with regard to the variations in business and consumption in the two decades before twenty per centum had been struck off from all the returns for 1870. In making this change we are accepting the gold standard as uniform; and it has never been doubted that gold is a better standard than a mere promise of gold, a probability of gold, whose value has not only all the uncertainties attaching to gold itself, but in addition to these the greater uncertainties attaching to the power and disposition of the government to make good its promise. To assume gold as intrinsically the uniform measure of values, without further reflection than is founded on seeing it accepted in the coinage of sundry countries, a distinction which it owes to the physical properties that make it convenient, while the difficulty of procuring it insures us against a glut of it; this is only one step in advance of assuming that the word "dollar" always denotes the same value. It is convenient rather than convincing. Undoubtedly we can, if we please, arbitrarily define uniform value as gold value, and logically draw all manner of conclusions as necessary consequences from that definition; but that method is scholastic rather than scientific. Value is based on demand, and a demand so essentially conventional as that for gold would not form a natural foundation of value.

It seems eminently reasonable that the unit of value should be that which meets a unit demand; and two ways of estimating this latter unit—each of them a species with varieties—have been advocated. The first of these is by the composite or tabular standard: a number of articles of general consumption is taken to form a mean price, this mean being either a simple average, or one with its components weighted according to estimated consumption; the demand for a fixed amount of this average commodity is assumed as a uniform demand, and therefore as answering to a uniform value. By this reckoning, if the gold price of the adopted average commodity falls, this is accepted as proof that the demand for gold has relatively increased, and that therefore we ought more properly to say that the value of gold has risen. In the second way of estimating, demand enters with a negative instead of a positive sign. We deal no longer with the good things of this life which man seeks to acquire, but with the hardships he seeks to escape. The typical negative demand is the curse of Adam, and so in the amounts of labor that this or that commodity can command, we

are to read its true value. The value unit is thus, like the great Joule unit of physics, based on energy. By this reckoning, if the gold price of the adopted unit of human effort—the average of several modes of applying it being used, to avoid variations merely casual—if that price rises, this is accepted as proof that the gold unit has lost part of its power to command human energy, and that therefore we ought more properly to say the value of gold has fallen.

Which of these two reckonings is the true one? Each of them in turn is again and again assumed as though no cloud rested upon its title. In one popular treatise on political economy—a work of many excellent points, by the way—the tabular standard, obtained by averaging carefully chosen proportions of some twenty widely-consumed commodities, receives the name of the "absolute" unit; and there is no lack of examples equally decided on the other side.[1] A thoughtful and skillful comparison of the two was made before this Section two years ago, in a paper on "The Standard of Deferred Payments" by Prof. Edward A. Ross, where the question was divided into two: "(1) as to the ultimate standard of value, (2) as to the destination of the benefits of industrial progress"—of which the second may safely be dismissed, because its answer is logically involved in the first. According to Professor Ross, "It is not difficult to show that the labor value theory rests upon a faulty analysis. A good possesses value or importance not on account of its past but on account of its future; not because it embodies past sacrifices, but because it promises future satisfactions. . . . As is evidenced by the course of trade between nations at different economic stages, values are determined not by cost but by utility." True, value is something that looks forward and not backward, and so regards not the cost at which the good has been attained in appraising its value; but however effective this now generally-admitted truth may be in overthrowing the doctrines of David Ricardo, it does not yet take the life out of the labor-value theory, for the simple reason that that theory, or the form of it which concerns us at present, really rests, not on the "faulty analysis" which Professor Ross so easily exposes, but as essentially as the commodity-value theory on utility. It reckons value not by the labor a good has cost, but by the labor that that good

[1] The question "Has Gold Appreciated?" is discussed in a recent pamphlet by Mr. C. C. Jackson, and answered on the labor-value principle in the negative.

will command, in exactly the same way that the rival theory considers the commodity that will be rather than that has been paid, in the same reckoning; and utility enters the equation with a negative sign, because labor is precisely negative utility. There is of course a real foundation for the contrast between "past sacrifices" and "future satisfactions," since when we regard the case of money in the hands of a wage-earner the labor represented by it belongs undoubtedly to the past and the commodity to the future—this being a consequence of the law by which men must earn before they can spend. But this is not the whole of the matter; the prudent wage-earner always looks on beyond the satisfaction promised from the commodity he would have, to the cost of replacing the money expended—if I buy this article, he says, I must do a day's or a week's work before I can regain an equal power to supply my wants. Plainly then, the order in which money payments are made should not be regarded a vital point, in fixing on a standard of values or of deferred payments. Professor Ross rightly treats this question, affecting as it does the equity between debtor and creditor, as mainly ethical; but there is as little equity in paying the working man for less labor than he expended, as in exacting of the debtor more commodity than he gave. Negative utility is ethically no less important than positive.

If it has been thought worth while to meet the attacks made upon the labor-value theory by those committed to its rival, this has not been from any notion that labor of any kind, or even of a great many kinds cleverly averaged, gives us the infallibly true standard of values. In truth, either of the two proposed scientific measures of value, if applied with logical thoroughness—if subjected, in other words, to conditions that really test it,—leads to a glaring absurdity. It is needless here to reiterate the familiar distinction between value in use and value in exchange, or the demonstration that one of these is not at all proportional to the other. The commodity theory substitutes use-value for exchange-value, where the latter is manifestly the thing sought. It pays close attention to demand in its estimates, and none at all to supply. The obligation that might equitably have been discharged with thirty-six pounds of sugar at 14 cents is not equitably discharged with the same quantity at 4 cents, unless sugar is specifically named in it; nor can we pay it with a pound of aluminum at 60 cents, though the same pound might very properly have paid it when the price was

If this is true of sugar or aluminum, why should it be untrue of the average of twenty articles, all subject in greater or less measure to the same conditions of cheapening production? An effective *reductio ad absurdum* of the other theory has already been indicated in one of the quotations from the paper of Professor Ross, where he insists on the important difference in the value of the same amount of labor "between nations at different economic stages." The principle which is neglected in the proposed measure, is that the value of labor depends on the way in which it is applied, to a perhaps greater degree than on the amount of it. So far from being economically the same thing as labor directed by high intelligence, labor directed by crude intelligence is something so different that it seems almost absurd to call it by the same name. If labor in general is now better paid than it was thirty years ago, this is largely—perhaps altogether—because in so many trades, enough to beneficially affect the whole, men have learned to give it that better direction on which its higher value depends.

Unsatisfactory as are all the solutions hitherto proposed, there seems to be no other direction in which we can look. The uses to which the customary measure of value is most largely applied are in the purchase of commodities, and in the requital of services. It is in those relations that we most want it constant; and how, then, can we more suitably judge its constancy than by seeing that it shall bring the same amount of commodity or the same amount of service? Making exception of cases admitted to be extreme, and acknowledging the approximate and relative character of any results we may reach, that is about the best that can be done. Averages may be used to reconcile minor irregularities, where the quantities averaged are not too discordant; and wages may fairly be admitted on equal terms with prices, in making our estimate. There seems to be no valid ground for giving wages the greater weight, and it has already been shown that they should be allowed no less. But it is not worth while to combine wages and prices into a composite, by which all values are to be measured, for the absolute unit is a chimera. We can get along without one, however, after a fashion, by applying the simple principle that when two articles change in relative value, the change is to be charged to the one whose demand or facility of production has varied. Accordingly, we can at least be certain that aluminum, or petroleum, or steel rails will not do as a general measure of

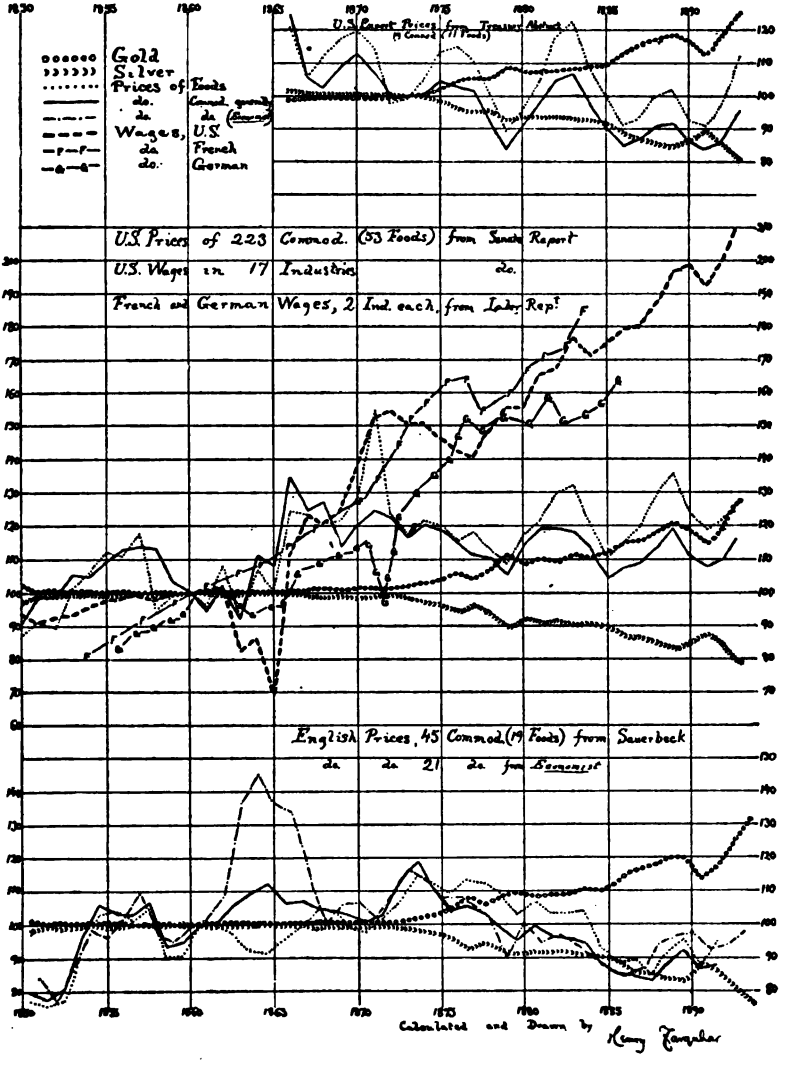
values, even without determining precisely what will do. In this way, under all reservations, we may set about the consideration of the question whether gold or silver has proved better adapted for the functions of a standard since the beginning of the recent changes in their relative value. We may be unable to devise, or even certainly to define, a stable monetary standard in any absolute sense, but we can determine whether the one or the other metal shows a nearer approach to our indefinite ideal, and even show more or less satisfactorily why.

The three diagrams which present this comparison to the eye are based on data from the Statistical Abstract of the Treasury Department, for the one at the top, and from the Report on Wholesale Prices, Wages and Transportation prepared for the Senate Finance Committee in 1893, by Hon. C. D. Wright and other officers of government, and collated by Prof. Roland P. Falkner, for the two below it. The two upper diagrams both relate to prices in the United States, the lowest one to England. In all of them the par value is made a mean proportional between silver and gold, so that the two metals vary reciprocally with reference to it; they are denoted by crescents and circles respectively. The full line denotes, in the middle diagram, Professor Falkner's means of all the two hundred and twenty-three articles of the Senate report, weighted according to consumption, while the dotted line is the indiscriminate mean of the fifty-three articles included as "food" in the same list. Corresponding to these, the upper full line is a mean, here unweighted, of nineteen articles in general use—sixteen of the prices are export rates, and three others (Ohio wool, soft coal and pig iron) as reported by dealers in the Treasury Abstract. The dotted line is a mean of eleven export prices of foods. The full line in the lowest diagram is the general mean from Sauerbeck's list of articles; this is preferred because fuller and in slightly better correspondence with the United States figures than the *Economist* list, which is also added in the broken-and-dotted line, for the most part closely agreeing with it. The lowest line of dots only is a mean of the three columns headed "Vegetable foods," "Animal foods" and "Tea, Coffee and Sugar" (the last having half weight, in the summary of Sauerbeck's relative prices.) Broken lines in the middle diagram show the movement of average wages, Professor Falkner having weighted the means for seventeen out of twenty-one different industries, proportionately to the number

Rep't	Wages; C. L. Rep't	
Econ. Comm.	French C & I. O.	German C. S. & W.
84.5		
76.6		
87.6	80.2	
98.8		
96.4		82.8
102.5		87.2
109.7		88.8
96.5	95.3	91.2
95.2		92.9
100.0		100.0
102.6	103.2	99.3
109.7		98.0
136.4		93.4
145.2	109.0	95.5
136.2		96.4
123.7	116.1	107.1
116.5		108.1
100.7		110.9
106.2	125.4	111.8
106.9	128.4	115.5
102.1		98.0
109.9	145.0	123.7
116.8	153.8	129.9
113.4	159.0	134.8
108.0	163.5	139.8
108.3	164.8	152.2
105.6	154.2	148.5
100.9	157.4	152.6
89.9	161.0	152.0
100.3	168.4	150.9
94.6	171.8	159.2
96.6	173.7	150.1
94.0	184.3	152.5
91.1		155.4
86.5		162.9
84.4		
86.9		
94.6		
96.2		
97.4		
92.6		
94.0		
97.6		

8 October 1892: gold 126.5.

RELATIVE PRICES AND WAGES; GOLD AND SILVER VARYING RECIPROCALLY


Gold
Silver
Prices of Foods
do. Comm'd. goods
do. do. (Comm'd)
Wages, U.S.
do. French
do. German
U.S. Prices of 223 Comm'd. (53 Foods) from Sauerbeck Report
U.S. Wages in 17 Industries do.
French and German Wages, 2 Ind. each. from Labor Rep't
English Prices, 45 Comm'd. (19 Foods) from Sauerbeck
do. do. 21 do. from Economist
Calculated and Drawn by Henry Farquhar

engaged in them by the Census. All prices in the Senate report are compared with those for 1860, and there seems to be no good reason for changing this. As the Treasury Abstract prices go no farther back than 1866, however, a different date had to be chosen[1] with them, and that fixed upon was the mean of the three 1872-74. In the Senate report, prices are given in gold as well as currency. The Treasury prices for 1866 to '78 are here reduced to gold by dividing by the mean gold premium for each fiscal year. The ratios having been thus put on a gold basis, they were reduced to the chosen mean proportional basis by first comparing the ratio of gold to silver for each fiscal year (upper diagram), each January (middle diagram), and each calendar year (lower diagram), with the values, 15.78 (for mean of three years, July, 1871 to June, 1874), 15.19 (for January, 1860), and 15.29 (for whole year 1860), respectively; and then multiplying each gold price by the square root of the corresponding ratio of ratios so derived. It may, perhaps, be worth while to add that the reason why neither gold nor silver was chosen as a standard of value, but a geometric mean of the two, so that the rise of value in one of them is exactly offset by a proportional fall in the other, is not because of any notion that such a mean has any practical significance whatever, or ever could have, or that it is desirable for the purposes of any other statistical inquiry than this; but simply because, in deciding between two alternatives, those alternatives ought to be treated as impartially as possible, without discrimination of Trojan and Tyrian. Whether the gold or the silver standard is more nearly followed, is in these diagrams not a question between curve and straight line, but between two curves of opposite course.

The use of the upper and lower diagrams is mainly to confirm the middle one, which is best adapted for the proposed test, because founded on more widely derived and better digested data. It will at once be seen that the two upper curves of price have nearly the same relation to each other, and the same general direction as the corresponding middle curves, though taken from an independent source, made up of far from identical (though similar) elements, and very differently treated. Both show a lower height, indicating a lower relative price for the foods than for the other items in 1866, while after 1875 the foods through all vicissitudes are de-

[1] A discussion of these prices by Mr. E. B. Howell, in the *Review of Reviews* for October 1893, adopts 1873 as the standard.

cidedly and continually higher. Notwithstanding this divergence, the direction of both, after 1866, is more nearly that of the silver price than of the gold; following the former even in its details until 1880, and after that becoming somewhat more nearly parallel to the latter. But it makes a significant difference whether 1872-74 or 1860 is taken as our date of reference. By choosing the former, as in the upper diagram, prices are made to follow silver very closely indeed; whereas the 1860 date brings the prices of the last fifteen years to substantial uniformity compared with gold. The price-curves for England, at the bottom, agree in showing a general diminution after 1873, and no such diminution, but on the whole an increase, before that date. Allowing for the violent changes of our civil war, in market prices as in many other things, almost the same words might be used to characterize the United States curves in the middle diagram; only putting the change of direction at about 1870 or 1871, or perhaps even as far back as 1866, instead of 1873. The relation in price between food-stuffs and commodities in general, is substantially the same in the Sauerbeck list as in the Treasury Abstract list and the fuller list of the Senate report; the foods generally lower for the former half, and uniformly higher for the latter half of the period considered. The divergence of the two from 1862 to 1866 is abnormally large and is fully explained by the effect of the single item, cotton, whose price was more than four times greater in 1864 than in 1860. The *Economist* list is generally in satisfactory agreement with Sauerbeck's, but its abnormal elevation from January 1862 to January 1867 is even more excessive, cotton being allowed a much greater proportional weight. The divergence after 1886 is more troublesome to explain, but it does not seriously affect the question before us. The effort to get hold of some indication as to the movement of wages in England, within the time here covered, has met with no success; the only statistics to be had are scattered, fragmentary, desultory, showing no approach to a continuous series for any occupation. Hon. Carroll D. Wright, in calling attention to a recent collection of statistical notes on the subject by Mr. Giffen, said that it would take some months' labor of a considerable clerical force, to obtain from them any results that could be used as indications of progress.

The wage statistics here depended on to show that the movement in this country is not exceptional, are some scanty and limited

returns of coal and iron-ore production in France, and from the cotton spinning and weaving industries in the German Rhine Provinces. The average annual wages per laborer, as tabulated in the first report of our commissioner of labor (on Industrial Depressions), appear to have been found by dividing the total wage-payment by the mean number of laborers; and in combining them, care was taken to allow weights proportional to the number employed; dividend and divisor were added separately, for a new quotient. No combination of French and German figures, in mining and cotton-working, was attempted. The results were compared with 1860 for gold-price ratios, then reduced to a mean proportional between gold and silver, as already explained. They are thus exhibited on the middle diagram, being distinguished from United States ratios by the letters F and G. It will be seen that the course of European wages, so far as we can infer it from these very scanty data, corresponds fairly well with that in this country, shown by the heavy broken line. The general, upward course meets a few interruptions in each line; these, in the French and German cases, may very possibly be incidental to the special industries examined. The first exception to the general rule of increased compensation in this country occurs during the civil war. Wages nominally increased in those days, every year; but the currency in which they were reckoned lost in value much faster than they increased, so that real compensation fell off as shown. Wages, as is well known, change more slowly than prices; so that, as already indicated, a depreciation in the unit of values makes those who depend on them the worst sufferers. The price-lines, it will be seen, do not show the effect of depreciated currency during the period nearly so much as the wage-lines. The second exception marks the great industrial depression of 1873–78, the third the minor depression of 1884; and the fourth, the one which began in 1890, and is still continuing. In the chart, there appears to be a sudden depression for 1891, followed by a rapid increase, but that appearance is due to coïncident changes in the price of silver. Following the gold standard, and taking account of relative importance, wages rose suddenly in 1889, but became substantially stationary in 1890 and 1891, and showed a very slight falling off in 1892. The figures for 1894, if they could be had, would doubtless show a grievous downfall.

Now, in answer to the question, which of the two metals furnishes

the better monetary standard, the diagrams have a great deal of important information to give us. First, as to the general run of prices of commodities since 1873, when the change in the gold-to-silver ratio first became considerable. The upper diagram shows that prices have followed silver and not gold. The middle diagram likewise, for it is by direction that we must judge, not position. The lowest diagram shows the same thing for England, with even greater emphasis, general prices having there fallen relatively even to silver; though this is less marked with the *Economist* than with the Sauerbeck figures. There is a difference between foods and production in general, the former having had less share in the general downward tendency. This is a consequence of the fact that recent mechanical improvements, bringing greater economies of production and transportation, have affected foods less than other commodities. If the use of a measure of values is to preserve uniformity in general prices, under such conditions as have obtained since 1873, then unquestionably silver is a better measure than gold. Next, carrying the limit back to 1860, we find a noteworthy difference in the answer. As a representative of prices about 1860, as the middle diagram shows us, gold has for the last fifteen years answered very well indeed in the United States. It has the same purchasing power that it had then, far more nearly than silver has. But, strangely enough, the same rule does not hold for England. There, prices still follow silver, and keep strikingly close to it if we consider how careful that country has so long been to accept only gold as its measure of values. What is the reason of this difference? A closer inspection of the price-curves appears to confine it within a few years. There is no very important and lasting divergence between our curve and the British, down to 1862, nor after 1866; for such fluctuations as appear in either disappear again after a few years. But between those two dates there is shown a heavy increase in prices in this country, British prices for 1866 remaining almost exactly what they were for 1862; which increase has not yet been offset by a relative decrease. If the U. S. prices for 1866 had been held down to equality with 1862, and had followed afterward the same course they actually followed, they would have been very like the British, and have kept closely to the silver line. The explanation of this increased scale of prices in those especial years is found in our revenue legislation, which then underwent its most significant modifications. If we regard

the movements of prices in England, where there have been no overhaulings of the tariff, as the normal movement, our conclusion that silver has been better adapted than gold to exhibit uniformity in prices of commodities, remains undisturbed by further extension of the period considered.

But a constancy over long periods of time, it has been already shown, is less important in a monetary standard than a steadiness in opposition to shorter and sharper fluctuations. There are several cases, within the time here covered, of sudden changes in the relative price of gold and silver; these are represented on the chart by steeper slopes of the gold and silver curves, which mutually approach or recede. Consider first the years 1875–80, where gold shows two rises and two falls in value, and silver of course the reciprocal changes. Prices, as shown in the middle diagram, follow silver with a fidelity, which in the case of foods is quite remarkable. The upper diagram shows the same thing, only the changes in the commodities have a greater range. English prices are less decisive for this period, since they seem to follow gold about 1876 and silver about 1879. Consider next the years after 1888, where the changes are of still greater range and abruptness. Here the price-curves follow gold in all three diagrams, thus appearing to show that these important changes affected only silver and not commodities in general; or, in other words, that it was not gold that altered in value. It may be claimed that this following of gold is merely an evidence of the conservatism of prices, taken in connection with the fact that our business is done on a gold basis; so that, if we had regulated our prices by silver, they would have been comparatively uniform in that metal, while gold would have appeared to be the wanderer. Professor Laughlin insists that this very question has been recently tested in Santo Domingo, where the currency was silver, the unit a Mexican silver dollar, and yet prices fluctuated with regard to it, whenever its value fluctuated with regard to gold. But this may be taken as proof, not that gold was inherently the steadier metal, but that markets in Santo Domingo, a region of only 400,000 population, are too strongly influenced by prices in this country to show what they would be independently. India, a country great enough to have a market of its own, does not show the effects noted by Professor Laughlin. It may reasonably be admitted, therefore, that the claim has something in it, and that the conservatism of prices, already

mentioned, after all forms a far more important factor in resisting these most dangerous changes than the choice of the better adapted metal.

Another very significant point should be borne in mind, in the same connection. The fluctuations of prices which run their course in short periods of time, the very fluctuations against which it most concerns us to guard if possible, were even greater before the two metals so widely parted company in 1873—not only in this disturbed country, but in the comparative quiet of Great Britain—than they have since been by either metal. The food-curves then showed very little more irregularity than those of general prices, and the great upward movement which followed the California and Australia gold discoveries, the reaction attending the commercial depression of 1857, the rise in cotton due to our civil war, and the effect of our increased tariffs, all occurred while the gold and silver ratio continued nearly uniform. Were it not for the existence and importance of this fact, it would hardly have been worth while to continue these diagrams back of 1873. But the proof that we here have, that the greatest oscillations in price come from causes with which divergence in metallic standards has nothing to do, ought not to be overlooked when we are estimating the importance of inquiries into metallic standards.

To the principal irregularities of the heavy broken line, showing the mean wages of labor, regard being had to the number engaged in the different occupations, attention has already been called. Passing over these, which are chiefly downward turns, symptomatic of our greater and lesser industrial depressions, and comparing the curve with those for the two metals since 1873, we see not a single instance in which it shows a change in direction agreeing with that of the silver curve for the same date; while its correspondence with the gold curve, even in its minute changes, is as striking as is its general agreement in direction, whether we start from 1873 or from a remoter date. We find the upward turn in 1877 and the curious alternation of higher odd years and lower even years between 1878 and 1885, in the gold curve, faithfully mirrored in the wage-curve; as are the downward turns of 1886, 1889, 1890 and the upward turns of 1887 and 1891. If this correspondence be ascribed to the conservatism already spoken of, which would naturally show itself even more in wages than in prices—if it be said that a negative proof is valueless, and that quotations habitually

given on a gold basis might not unnaturally show little variation by comparison with gold—it is clear that no such criticism will apply to changes in the direction of the gold changes but exceeding them in amount, to appreciation of wages relatively to gold while gold is itself appreciating. And yet nothing can be clearer to the eye, than that that very thing is what wages have done since the return of peace to our land. And just that have wages done in Europe at the same time—starting at a lower point, bringing up at a lower point, but following the same general rate of increase. Manifestly the just measure of wages, in the period here covered, has not been silver. If it be desirable on any account to preserve a constancy in the compensation of labor, to provide that the sum which represents so many days' work at one date, shall not represent fewer days' work at a later date, on that account is silver inferior as a standard. Its claims can be upheld only by proving the unfitness of human labor as a measure of value, and that has not been done.

If the labor-standard is faulty, as here applied, in testing the gold and silver standards, it is faulty by its too great tendency to indicate depreciation. This results from the fact that the labor performed in a given trade, to-day, whatever pains we take to pick out trades of the same name and as nearly as possible identical, is not precisely the same thing as the labor performed in it twenty years ago. It is different because its application is different. In many lines, furnished with more effective tools, guided by better-educated minds, its product is greater and there is more to pay it with for that reason; and the rise of wages in these lines brings about a general advance, though the intrinsic quality of the labor may be unchanged. On this account the true measure, supposing that measure determined by a regard for intrinsic quality and not extrinsic application of labor, would be one by which wages as here treated should somewhat increase. If the commodity-standard is faulty, on the other hand, it is faulty by its too great tendency to indicate appreciation. The value of a commodity which can be supplied by the hundred-weight becomes a very different thing when the same plant, force, enterprise and capital can supply that commodity by the ton. Though its use-value remains unaltered, the depreciation of its exchange-value is a real phenomenon, and must not be neglected in testing a proposed standard. And since there is no valuable that has not a wide range of other valu-

ables for which it is capable of serving in one way or another as a substitute, the cheapening of one of them, by newly devised economies in production or distribution, brings about the cheapening of a whole group. On this account the true measure, supposing that measure determined by articles for which not only the demand but the facilities for supply remain steady, would be one by which prices as here recorded should somewhat decrease. In fine, the best standard of value would be one whose changes were intermediate between those of wages and those of prices. Silver has represented prices well, though in its very latest plunges it is beginning to outstrip the general run of articles in the downward course, while it diverges widely and hopelessly from wages. Gold, by the same evidence, is rising a little with respect to prices, as there is good reason to believe the accepted standard ought, and at the same time falling with respect to wages, as there is equally good reason to believe it ought. This appears to be a thorough and impartial statement of the facts of the case, so far as these data suffice to furnish them. The champions of silver are entitled to fair treatment, and their predilection for the cumbrous name of bi-metallist, while they reserve an even more cumbrous name for those unable to see as they, need not prejudice us against their cause, however like a confession of weakness this eagerness to fly to shelter may seem.

There is a satisfaction in the conclusion that, however we may account for it, the measure of values generally accepted among enlightened nations so happily combines the qualities that the true measure ought to possess, and this is ample compensation for the trouble taken in collecting and setting forth the evidence on which that conclusion is based. Nevertheless, it should be distinctly borne in mind throughout this inquiry that the question just considered—whether gold does or does not meet the conditions of stability—is one that, however interesting it may be from the point of view of the student or the philanthropist, has no necessary bearing on the practical question—whether gold is or is not destined to become, or rather to remain, the universally recognized standard among peoples whose recognition is a matter of any significance. If a careful examination of the question of stability had showed gold to be as inferior to silver as due attention to the course of wages has proved it superior—as inferior, let it be admitted, as a consideration of prices only, since 1866, would show it—the con-

clusion would remain yet unshaken, that the future belongs to gold. Better to understand how this may be, let us consider an illustration from another branch of economics. About a century ago, the power-loom and spinning-jenny came into use, also the improved steam engine. The united effect of these was, as has been often explained, to make certain production, particularly that of cloth, more profitable when done in large quantities, and thus to establish the factory system, breaking up, for purpose of general use, the older method of home production—production in small quantities, at places wide apart. Watt and Hargreaves were followed by inventors only less well known, all working to the same end: to build up, aggrandize and consolidate the factory, to enlarge and condense the town. The results of the change, in amount of cloth produced per human-producing unit, have been mighty, but its effects on the minds, manners and morals of the workers are open to grave question. Are men better for being packed in such close masses, so reduced to appendages of the machines they run? How do the smoke, filth and bad air of huge factories and the towns where they necessarily aggregate, compare in healthfulness with sky and field and home? These questions have been often asked, and made a serious impeachment of the factory system. But another question has always arisen, which has remorselessly swept all these aside: even if the abolition of factories should be proved desirable on all these counts, is it practically possible? In face of that inevitable, inexorable question every humanitarian or philosopher is driven from the discussion—unless it be Mr. Ruskin. In simple truth, the social force which has been set at work in building and driving these factories has grown too strong to be controlled by any social force which discussion can set at work to fight them. Something of the same sort exists in the case now under consideration. Gold has supplanted silver as a standard throughout the countries which make any large use of money, because economy has compelled it; and that compulsive force has by this time grown too strong to be counteracted or controlled by any question we may raise of its superiority or inferiority to silver in carrying out the demands of ideal justice. It is not contended that things ought to be thus, so much as that they are thus.

No treatment of monetary standards can have any claim to completeness if it neglect to make respectful mention of the system of "puts," and to enquire how far the introduction of puts is an aid

to the just performance of contracts, or an improvement to the general financial scheme. The put, it is almost superfluous to explain, is a bargain which binds one side and leaves the other free. Doe gives a put by agreeing to pay at such a time such a sum for such a quantity of some article—generally a speculative stock—provided Roe chooses to sell. Roe, who holds the put, is himself under no obligation. This practically amounts to a bet on the price of the stock, in which if Doe loses he forfeits the difference between the named price and the market price, be that much or little; while Roe's forfeit is in any case the consideration of his option, which is usually cash paid to Doe. The point of chief importance for present purposes is that the option is not obtained by Roe for nothing. Whatever is worth having must as a general rule be paid for, and no one expects to have a put given him gratis. As applied to the monetary standard, the put system allows a pecuniary contract to be discharged by an option between two metallic expressions of value at a predetermined ratio; that is, it involves a species of bet on the relative market-price of the two metals. If the advocates of puts in monetary contracts were content to have them permitted for those desiring to enter into agreements of that kind, there might be none to take the field against them; but when it is seen that their object is something more comprehensive, to connect this form of speculation universally with every contract involving a future payment of money, whatever may be the intention or disposition of the contracting parties—then it is not unreasonable to enter a protest. This protest need not leave out of view the fact that all contracts for future payment involve a speculative element inseparable from such uncertainty as may attach to the constancy of the standard of payment, nor the fact that the option which it is proposed to allow, to one of the parties only, is expected to make the contract more equitable and even between them; it need only speak of this law-imposed put as a needless complication of something that ought to be as plain and easy as possible, and as a piece of unvarnished paternalism. It might also point out that such an imposition is no favor whatever, in the long run, even to the class it is especially devised for the purpose of favoring; for, just as other puts are sold and not given, so these, if there is anything in them of value to the possessor, can only be had by his paying the cost. This payment will probably take the shape of higher interest charge—that being the general accompaniment of all forms of uncertainty that a loan will be fully repaid

—or else it will be what comes to practically the same thing, a shortening of the supply and greater difficulty in the obtaining of loanable capital. One of the alternative standards of value, indeed, is quite as likely to grow cheaper by unforeseen as by expected causes, and the prudent lender will always guard himself against every risk, in the terms on which he grants his loan; so that the borrower, who is put at additional charge for insurance, in the shape of higher interest, against that very cheapening of the alternative metal which is expected to delight all borrowers, must, in case no such cheapening come to pass, be only a loser by the option allowed him.

When the market price of either metal, the debtor holding an option between two, goes below the designated ratio, that metal becomes the standard of values. While this state of things lasts, the other metal is not in any real sense the standard, but that standard will be something that rises and falls with all fluctuations of the cheaper metal, so long as none of those fluctuations carries its price above the ratio fixed. In the changes since 1873, therefore, if the laws had decreed either gold, or fifteen and one half or sixteen times its weight in silver, impartially, to be the standard of deferred payments, the facts of business would have been in all respects as if silver alone had been made the standard, with no option at all. This is not doubted, but associated with it is an interesting question, as to which the widest diversity of opinion exists. If silver had been made standard money, in the countries for which these diagrams of prices were made, would its value relatively to other articles, and gold especially, have taken a course anything like that it did take? The advocates of a nominally alternative standard, or of puts in monetary contracts, or, if they prefer, bimetallists, maintain with great energy that the relation of silver to gold, at least, would have been in that case very different. They appeal to the course of the two metals from 1850 to 1857, shown in its relation to prices on the chart. The unparalleled increase of the gold supply which then occurred had no further effect on the ratio than to bring down the gold value from about 15.8 to about 15.3, a difference just perceptible at the extreme left of the chart, even the highest quoted price of silver at any time in London, 62¾, yet giving a commercial ratio a little above 15. Such an insensibility is without precedent, even in the history of money metals. Ascribing it to the legislation of a fixed ratio by France, it is easy to argue that if that country had held as firmly to its coinage sys-

tem after 1873, the commercial ratio of gold to silver could in like manner have been kept steady. We might have seen a phenomenon like that shown in these diagrams from 1850 to 1857, a sharp rise in prices, indicating a greatly diminished purchasing power in money of both kinds, but no significant change in the ratio of the metals to each other. There seems to be no good reason for denying any part of this claim, except the reason alleged for the steadiness of gold after the California discoveries. If the laws had held the two metals to a fixed ratio as legal tender, and if those laws had been carried out, there could have been no such change, and all the inconveniences we have suffered therefrom could have had no existence. Very similarly we might say, if the factory system were abolished by a statute, and if that statute were obeyed, the evils of that system would not exist. The two propositions are equally undeniable, and about equally practical.

There is no lack of able essays and treatises in advocacy of the monetary system known as bi-metallism. This Section had the pleasure of hearing one a few years ago from Mr. E. T. Peters, which insisted strongly on three points, among others: that restricting the monetary use of either metal was, in effect, restricting the supply of money, and throwing too much work on what remained; that any ratio of value legally established (say 15½ to 1) would necessarily become that of marginal cost of production; and that international agreement was essential to successful bi-metallism. Earnest and eloquent have been its partisans in more than one country of Europe. Some of the pleas in its favor have swollen to the dimensions of volumes. But it seems sufficient to take a recently published pamphlet, "Bi-Metallism, a Tract for the Times, by Francis A. Walker," as an epitome of the entire argument. Certainly nothing could be fairer than General Walker's opening:

"Three successive questions are involved in the problem of bi-metallism. First, is it economically desirable, and this in a high degree? Second, is it economically practicable — that is, if the system were set up, would it work successfully under the normal operation of the principle of self-interest, without any help from philanthropy or public spirit or patriotism . . . . ? Third, is it politically and diplomatically possible — that is, can the consent and coöperation of a sufficient number of nations be secured to set up and sustain the system, if indeed it be economically practicable?"

General Walker's second question is admirably stated, but his discussion of it gives no satisfactory answer. To summarize it in a few sentences:

"Law cannot affect values, much less control them, except as it sets some economic force in motion. . . . . This was exactly what France did by the law of 1803, which established the bi-metallic system. . . . . This system accomplished its purpose to a degree which is truly marvelous when one considers the tremendous power of the forces by which it was unexpectedly assailed. As before stated, in 1803 about three dollars' worth of silver was being produced for every dollar's worth of gold. In 1809 began that long series of revolutions and rebellions in Mexico and Spanish South America which destroyed the mining industry of those countries, so that silver production fell off with frightful rapidity. Then gold was discovered in the Ural Mountains and in the auriferous sands of Siberia. . . . . In 1848 came the discovery of the marvelous gold fields of California . . . . and only three years later . . . . of Australia. Within twelve years the stock of gold in the hands of civilized men was literally doubled! . . . . The part which the French system played during the seventy years covered by this narrative, especially during the gold deluge, has been acknowledged in the fullest manner by gold monometallists of the highest authority. [Quotations from Jevons and Bagehot follow.] . . . . 'In all the crises that have arisen, at epochs so diverse, in circumstances so different, one sees the Bank of France less distressed than the Bank of England. . . . . We may affirm without rashness that the French monetary system is not without influence in the result.' [M. Denormandie.] . . . . The three great purposes of bi-metallism are, as we have stated them: first, the establishment of an approximate par of exchange between gold-using and silver-using countries; second, a higher degree of stability in the money-mass compounded of the two metals than would be attainable under monometallism; third, to prevent the disastrous results which might otherwise follow the depreciation or appreciation of one of the metals, through its increasing abundance or scarcity. . . . . So long as France secured these great benefits to mankind no one but the French . . . . had the right to object to this alternation of gold and silver in their currency; but they did not do so."

To understand rightly the circumstances under which the French coinage of 1803 was enacted, we ought to have under our eyes Dr. Soetbeer's table of the mean gold-to-silver commercial ratio for each year. This ratio, for the greater part of the last century, was under 15. It was slightly over that figure in 1748 and in 1790, between which years there is but one break in the run of 14's which denote the whole-number part of the ratio. Professor Laughlin has testified to the exactness with which the ratio was fixed at 15, when this country first began coining in 1792. By 1803, 15½ had come to express the same thing as exactly. The ratio still increased for a while, irregularly; a few 16's appear in the table from 1808 to 1813. Is any doubt entertained in any reasoning mind that this important relative increase in the value of gold, from 1790 to 1813,

was due to the fact adduced by General Walker, that at that time "about three dollars' worth of silver was being produced for every dollar's worth of gold?" And if rising production and falling price were cause and effect, was not the cessation of the effect due to the cessation of the cause, when the disturbances in Spanish America began in 1809? If silver production had kept to the figure it reached in the first years of the century, it appears altogether probable that this depreciation would have continued, that the French bi-metallic system would before long have collapsed as totally and hopelessly as our own first bi-metallic system, and that the French surrender of 1874 would have come when ours came in 1834. From that fate the French system was saved by the diminished silver production, which thus proved, instead of a force that "assailed" it, really the force that sustained it. The fall in the price of gold in 1850, happening as it did when the coinage of France had become almost exclusively silver and her bank reserve was eleven-twelfths in that metal, when gold had disappeared from general circulation and commanded a premium at the Exchange, gave her bi-metallism a new lease of life. But for a few years only; its failure was practically acknowledged when the country consented to use debased metal, coined on government account and redeemed by the government, for her small-change silver; so that its subsequent abandonment (under the name of suspension) was natural enough. It is interesting to note that the forces which assailed the French system with such "tremendous power," but which were successfully resisted, were all of them forces that tended to arrest the downward movement of silver. In the presence of a force that hastened that movement, bi-metallism succumbed without a struggle. With the nature of the force that thus brought it low, we need not long detain ourselves. General Walker hotly insists "that it was silver demonetization, and not silver production, which caused this tremendous effect;" but the reconciliation of this view with that of "the tremendous power of the forces," etc., quoted above, and with his admission that supply as well as demand affects all prices, may be left to him. He hurls his wrath against the Germans as chief sinners in this "demonetization" movement, not even once alluding to our own Mint Act of 1873 as "the crime of the age." The fall of silver was certainly coïncident with these demonetizations, and may perhaps have started immediately from them, but even so we may ascribe it to increased production without any mis-

givings, just as we might ascribe the fall of an unsafe building to its unsafety, even though we saw it pulled down by the building inspector. Whether it was German or American breath that overturned this house of cards, need not greatly concern us. Since "law cannot affect values much less control them, except as it sets some economic force in motion," the "tremendous effect" of demonetization laws is explained by their cutting down the monetary demand for silver; but this supposed force did not exist. More silver was coined in 1876 to 1880, according to Dr. Soetbeer's tables, than in any preceding five-year period. The amount has since diminished, but is still higher than before 1866. Whatever the reason for the decline was, however, that reason was and has remained sufficient for France.

No unprejudiced mind would be indisposed to credit France with having shown some power over the relative value of gold and silver, in resisting and alleviating its changes, down to the opening of the Comstock era in 1870. Some power it may have shown, perhaps, even though the claim now and then made by people imperfectly acquainted with the facts, that "between 1803 and 1873 it maintained for the whole world the ratio of 15½ to 1" is inadmissible.[1] But since it is at best a matter of conjecture how far the falling off in silver production after 1809 would have lowered the gold ratio, how far the subsequent recovery would have increased it, how far the California and Australia discoveries would

[1] Yet that claim is repeated by "the bi-metallist members of the German Silver Commission," whose declaration "is regarded by President Andrews as one of the most telling and weighty summaries of the case for bi-metallism that has ever been made." These Commissioners also discover an "increased power of competition" in cheap-money countries: "In proportion as their silver or paper loses in power to buy gold, these countries enjoy in effect a high export premium"— as though receiving less return for their productive labor gave them a real advantage. The declaration further declares: "The attempt to refer this lowering in the general level of prices [since 1873] to other causes, lying outside the coinage system, for instance to cheapening and improvement in means of communication, to the perfecting of processes and machines for the production of goods, etc., must be considered a failure, for the reason that the same causes were present in the same strength during the twenty-year period before 1873"— which they were not. The development of the Bessemer process belongs to the later period. Average freight-rates per ton-mile on seven important railways were 1.89 cents in 1872 and but 0.75 cents in 1892. (See Senate Report, page 615.) The fact that "wages have increased in price is without weight, because . . . . wages rise with the elevation of the standard of life in the different classes of the population"— which they do, just as the boy grows larger when he comes to wear larger clothes. The conclusion appears to be that "a stable ratio might be maintained IF the nations we have alluded to [Great Britain, the United States, Germany and the Latin Union] were to accept and strictly adhere to bi-metallism at the suggested ratio." Doubtless. (Translation by Pres. E. B. Andrews in *Review of Reviews* for October, 1894.)

have lowered it again, and how far the reduced yield from these rich stores, accompanied by a steadily increasing silver yield, would have restored it—effects all plainly traceable in the ratio as it is—how much more strongly traceable they would have been if France had left the metals to their fate, it is impossible to tell with any approach to certainty what the exact influence of France was. The violent changes in the ratio since France gave up her bi-metallism are not a sufficient answer; for if those changes have been unprecedented in their rapidity and extent, the increased silver output since the Comstock discovery has been equally unprecedented. It is true that there had been unprecedented gold discoveries just before, which were prevented, by France or by some cause, from lowering the ratio below 15; but this brings us to a point that seems to have escaped the analysis of bi-metallistic authors, namely, the difference in the kind of demand filled by gold and by silver in this nineteenth century. For very small payments, silver is of course indispensable; but that is a demand soon satisfied. For large payments there is a preference for gold, which increases with the size of the payment to be made; so that, on account solely of superior convenience, there is a higher gold-ratio in countries where business is done on a wholesale scale and payments are large, and also an increasing ratio in the same countries as business operations grow wider. The difference in demand grows stronger with higher civilization, for differentiation of function is a distinctive mark of evolution. In view of this increasing preference for gold, a cause whose efficiency cannot be doubted, we have a reasonable explanation of the surprising insensibility shown by this ratio to the gold discoveries in 1848, and its marked sensibility to those of silver about 1870. This examination of facts is worth the making, because it enables us to account in a perfectly consistent and probable way for every phase of the gold-to-silver ratio that the century has seen, without crediting the French monetary system with any decisive share in producing or controlling them. The part played by France may have been nothing, or something, or anything short of everything; we cannot demonstrate, but only estimate; and even General Walker's "gold monometallists of the highest authority" do not settle the question. A combination of nations might perhaps have more power than France alone to fix a ratio, but it would also include more elements of weakness: national jealousies and rivalries, which would lead

some to shirk a work of this kind, whose benefits were to be common to all, while the cost would have to fall on each separately—would lead others to suspect their partners of shirking—and so on, until the agreement fell asunder by its own weight. The conclusion to be drawn, since the best evidence offered that international bi-metallism is economically practicable is the example of France since 1803, is that the proof is not sustained.

A few words on the alleged benefits of bi-metallic coinage. That of a "par of exchange between gold-using and silver-using countries" is real, and of no slight importance. It is of just the same nature as that of a steady price of cotton, from the recent loss of which some parts of our country have so greatly suffered. If bi-metallism is economically practicable, we might doubtless expect this benefit from it; if not, we shall be compelled to reconcile ourselves to fluctuating silver, as we have reconciled ourselves to fluctuating cotton. "To prevent the disastrous results which might otherwise follow the depreciation or appreciation of one of the metals," is what this device would do for us most imperfectly. A scarcity of one metal or a greater abundance of the other, it would tend to check by throwing the office of currency on the second, of course. If this happened to be followed by an opposite state of things, the remedy would apply itself automatically; but how if it were followed by more of the same state of things? if the scarcer metal grew still scarcer, or the plentier one more plentiful? The remedy would then have been already applied, and would be no longer available. There is no reason why things should take the first course rather than the second, though General Walker's claim that his system would result "in establishing an alternating circulation," is evidently founded on some conception that they would. To the claim of greater stability, that "with bi-metallism, shocks in trade come less often," the example of France is again brought for support. Unquestionably that country has had fewer and less serious financial disturbances than this country, or than England. But when we remember that the French do business more for cash and less for credit than we do, and that they are exceptionally particular to keep a strong cash reserve—for the Bank of France has held, steadily for the last twenty years, more gold alone than the Bank of England (most of the time more gold than all the banks of issue in the United Kingdom together) to say nothing of its equal hoard of silver,—it is quite needless to look beyond these facts to account for their immunity.

It only remains to sum up, in one paragraph, the results of an inquiry whose close relation to vital public interests is hardly sufficient to make it enlivening or entertaining; and then to see to what practical conclusions they lead. A monetary standard is constant when the same amount of money does the same work; as nearly as possible supplies the same want and compensates the same effort. These ends should both be attained if practicable; if not, neither should be exclusively preferred. The selection of centuries of civilization having fixed upon silver and gold as expressions of values to be taken as constant, the inquiry is, which of the two more nearly meets these ends, or whether a combination of the two would be better than either. The answer appears to be that by the ideally best standard the prices of average merchandise ought to have been slightly diminishing and the wages of labor to have been slightly increasing within the last twenty years, a requirement more satisfactorily met by gold; and that any attempt to work the two metals on equal terms into a composite whole is, in this era of telegraphs, railways and "ocean greyhounds" of very doubtful practicability and of very doubtful merit if its practicability were assured. The alleged scarcity of gold and "diminishing money supply" seem little more than a myth. The most important conclusion suggested is the needlessness of active interference in the matter by the governing power. Allowing entire freedom of contracts in money; construing the terms of such contracts in all doubtful cases according to prevalent usage, and enforcing them accordingly; granting to the people all needed facilities for immediate decision as to values in metallic form, by marks certifying to weight and fineness, this being the true function of coinage;—when the government has done these, it has done its part. The usurped power of passing "legal tender" acts should be surrendered, and legal definitions of value should cover only contracts made by the government itself. Were this course followed, men might treat as money anything they agreed so to treat, accepting the government's stamp as evidence that their agreement was kept, and not fearing or hoping that any meddlesome enactment would step in to declare that, though one metal was agreed on, the agreement might be completely discharged by paying 15½ times its weight of some other. If the result of this policy should be a victory for the economic forces now working to bring all nations to a gold unit in practical business, the standard

to which we should thus be brought, as amply shown above, is no bad one. If the contracting parties preferred silver, however, they might make their agreement in terms of silver, and have it so enforced; or if they decided on giving the debtor an option to pay one metal or "put" another, and so declared, the law might help them in that also. But it would not infer the put unless the contract explicitly provided for it. The question of the ideal standard would remain as now, interesting and altogether suitable for scientific bodies, but active business would never have occasion to wait for our verdict upon it.

In a total abandonment by the government of its power to declare a legal tender for private debts, is to be found the true practical solution of this problem, a Stable Monetary Standard.

PAPERS READ.

A FORECAST OF THE FUTURE COMMERCIAL UNION OF THE ENGLISH-SPEAKING PEOPLE. By EDWARD ATKINSON, Boston, Mass.

IN the time allotted to me I can only give a sketch of the beneficent conditions which must ensue when full assurance has been given that no further resistance will be made in the United States to the maintenance of the present lawful unit of value — a dollar made of gold — and when the removal of obstructions to future commercial intercourse between the United Kingdom, Canada, and the United States has been in part or wholly accomplished, and has had time to exert its influence.

I must deal as concisely as possible, first, with the influence which will come from the confidence that may be reposed in the unit or standard of value upon which our national and commercial credit rests; second, upon the great increase of exchanges of product for product which must follow the gradual removal of taxes upon imports. I must of necessity deal with my subject from our own national point of view. I may give you a dim perception of what we expect, what we hope for, and what may be our dream.

When I state my views of what we expect, I do not at present include the great body of voters, who may yet vacillate for a time; I mean by the profoun we that small body of students of the social order who comprehend the logic of events, and who take cognizance of the unseen forces which are now moulding public opinion.

When Abraham Lincoln said that the union of the States could not continue to exist if one-half were slaves and one-half free, he possessed a true insight long in advance of the mass of the people, and his forecast was fully justified.

I could now name a few men of the highest authority in economic study who would join me in declaring that the United States will surely maintain the single standard of value at the unit of a gold dollar, and who would also sustain me in my judgment that we shall, if slowly, yet surely, remove all obstructions to international commerce that can be done away with by legislative action.

I do not myself address you as a student only. I speak almost wholly from the standpoint of an observer of the forces which are now in action who has been occupied in the practical affairs of life more than fifty years. I have twice called the attention of the British Association to the dominant power of the United States to supply wheat at a profit at prices which would leave no margin for rent on wheat land in Great Britain cultivated under the customary methods and conditions of the leases to tenant farmers. These forecasts excited many adverse com-

ments in England at the time they were made; some of them were bitter and even personal, but they have been justified. We are now entering upon a new chapter in the matter of wheat supply. The lands which have been devoted wholly to wheat in the upper Mississippi valley are being divided into smaller parcels by prosperous farmers who cultivate various crops, making wheat only a partial and to some extent an immediate cash crop, as its planting and harvesting can be conducted by the same force without interference with the other work of the farm. Under such conditions there is no sure method of defining the cost of wheat, and whatever it may bring, it is a sure resource of cash.

While this change has been going on, an area has recently been opened to cultivation and by railway in northern Texas and in the Indian Territory adjacent thereto, on land which had been heretofore devoted to and supposed to be only fit for grazing. This parcel is equal in area to the present entire wheat field of the United States, covering about sixty thousand square miles. It may probably compete even with the Argentine Republic, where our future most severe competition is to be expected, whenever a safe and stable government is established. We can, however, continue a full supply of wheat at a profit under conditions corresponding to those of the years 1891 and 1892, or at a normal rate of about 25 shillings a quarter in Mark lane, which is substantially the same as 75 cents a bushel in London. Such is my belief.

In respect to the unit of value, the logic of the case will ultimately control legislation. In the progress of my own study of financial history, I have become aware that a unit of value has been established at different times, in various countries or continents, of more than one kind, changing from period to period, and varying in different parts of the world at the same time, as it does now. This unit of value is the denominator of the price of other things, and the standard by which the relation of other things each to the other in the process of trade is determined. It must be a unit. No other than a single standard can be conceived. This process of natural selection antedates all statutes, decrees, agreements, or treaties. Putting aside all other things than metal as of no modern importance, the unit of value has consisted from period to period of a fixed quantity or weight of iron, copper, silver, gold, or their alloys. All statutes have been framed to correspond to these precedent conditions.

In order to maintain a just and uniform weight and quality, coinage was next invented. Governments afterward undertook to control the manufacture of coins, and decreed private coinage to be unlawful. The purpose then was to assure a just and even weight of metal in each coin, and the most nefarious and destructive acts of government have consisted in decrees or acts of legal tender conceived for the purpose of taxing people without their knowledge through the debasement of the coin. I have reached the conclusion that acts of legal tender were conceived in sin and nourished in iniquity. True money, money true in weight and quality to the name of the coin in which it is embodied, calls for no fiat or force of law in its use.

Men began to consume food before there were any statutes or regulations for its distribution. The same is true of fuel and of clothing, and of all other things. Men began to exchange the means of subsistence before there were any statutes or treaties affecting distribution; in the same way men began to use metals as money before there were any laws regulating the coinage of money,

and long before there were any decrees or statutes of legal tender. Legal tender flats or decrees originated in the debasement of coin.

As the interdependence of nations began to assert itself, and international commerce in the necessaries, as well as the luxuries, of life also began in very modern times, the necessity for an international unit or standard of value asserted itself. As time went on, without treaty, agreement, or the intervention of any international law, that unit of value became 113 grains of pure gold. The pound sterling long since ceased to be the silver pound of Troyes, which was probably brought over to England by the Easterling merchants of the steel yard. The words pound sterling have long since lost their original meaning, and have become a mere name for the weight of 113 grains of gold. In the progress of time every commercial country has enacted acts of legal tender for one cause or another, and has prescribed by statute what should be lawful money within its own limits, until the only commerce which is free of such interference of legal tender acts is the international commerce of the world. It is plain that without stability and uniformity in the unit of value, international commerce could not be conducted as it now is. Exchanges of products might continue by barter, but in view of the various kinds of legal tender or fiat money, which are now in enforced use within the limits of the separate nations which share international commerce, their exchanges with each other must either be conducted by barter, or the relative values of their products must of necessity be defined and measured by comparison with a unit of value. A single standard is essential. Duality in such a unit is unthinkable. These conditions exist. They cannot be changed by statute or by treaty, but all statutes and treaties must be adjusted to these conditions. If any attempt should be made to evade these conditions by acts of international legal tender, now advocated under a misuse of the word bi-metallism, it would be, therefore, an undertaking to give debtors a choice in the kind of metal in which their contracts made in their customary terms might be liquidated by them, and it would also of necessity deprive their creditors of all choice in the matter. Legal tender money is money which rests on force or fiat for its acceptance, whatever its quality may be, either good or bad.

Must not merchants or bankers then change the forms of their bills of exchange by giving up all the customary names of money in order to assure equitable settlements of account? Will they not then make them in specific terms of gold by the measure of weight, in grains or grams, as the case may be? Why not?

Under the present interdependent conditions and relations of nations the price of all the great staple products of the world is determined by the price at which imports and exports can take place. If an international treaty of legal tender were now agreed upon between Great Britain, France, Germany, and the United States, whose action it is said would control the action of other States, would it not at once become necessary for the farmers, millers, merchants, and bankers of the United States to devise methods of exchanging the excess of our products of grain and cotton for the products of other countries on exact terms? What other exact standard can be devised than a given weight of gold? Gold is now the only medium which will buy anything anywhere. It is the only universal money. Coin made of gold meets the fire test, which is the only test of true money; it is worth as much after it is melted as it purports to be worth in the coin, making allowance for seigniorage where any charge is made for coining.

In order to make this plain I must deal with the trade relations of the United States with other countries, because I am most familiar with them, and also because in the traffic of the United States with the gold standard countries of Europe we are now annually the creditor nation. These gold standard countries of Europe are the principal creditor nations of the silver using countries and continents of other parts of the world. If we gave to our European customers the option to pay for our grain and our cotton in silver or gold at their option, while depriving ourselves of any choice, it might be very convenient for them to collect silver from their own customers and to pay it over to us for the materials which enter into their manufactures. Would it be prudent for the United States, who are themselves producers of more silver than they can use, to grant such an option under any conditions? The facts may elucidate this problem, and may render it easy for every one to answer this question. That is the question which the people of the United States have lately put to themselves, and in my opinion their answer is emphatically No.

Putting aside the relatively small indebtedness of the United States to Great Britain for capital borrowed for investment, which is an unimportant factor, the United States are annually creditors of nearly every European State. We sell to European States vastly more food, fibre, and fabrics than we buy of them. On the other hand, the United States are annually debtors to Asia, Africa, South and Central America, and the West Indies, for sugar, wool, tea, coffee, rubber, and other tropical or semi-tropical products.

For the purpose of making this clear, I have taken the figures of the imports and exports of the United States in the year 1892, at a period when the previous bad harvests in Europe had caused a very great demand to be made upon us for the means of sustaining life. In that year our exports of domestic products were valued on a gold basis in excess of $1,000,000,000, or over £200,000,000, consisting about 80 per cent. of provisions and cotton. These provisions were necessary to the subsistence of the manufacturing or machine using nations of Europe, which produce less food than they consume. The cotton was necessary to sustain the exports of cotton fabrics from which Great Britain especially derives a considerable part of the means of payment for the food imported. The exports of Great Britain, Germany, Belgium, and the Netherlands are in large measure to the non-machine using continents of Asia, Africa, and South America, in which the money metal in chief use is silver. It will not be necessary for me to give the figures of the traffic of these countries with their foreign customers; it will suffice to show the general trend or course of trade of the United States in respect to exports and imports. For this purpose I have made two tables from the statistical abstract of the United States. From a summary of the figures of these tables it appears that the United States were creditors in the year ending June 30, 1892, on their traffic with European countries, to the amount of $458,826,383. They were also creditors with a few other countries, almost all of which were colonies or possessions of European States to the amount of $26,180,570. Total, $485,006,953.

That sum represents the excess value of our exports over the imports from these specific countries. This sum varies but a fraction from £100,000,000. To that extent we were entitled to draw bills of exchange at sight or on such other terms as might be agreed upon in each bargain or sale.

In order to disabuse the mind of any bias growing out of mere names, we might define this credit as consisting of 193,000 Troy pounds of pure gold, of 5,760 grains each. We exchanged our excess of provisions, grains, cotton, and goods which we exported for 193,000 Troy pounds of pure gold or their equivalent.

These transactions were all free of the interference of any act or treaty of legal tender. The bills were all doubtless drawn in pounds sterling, and the accounts were kept in that name; but, as every one knows who is conversant with affairs, all large cash settlements are liquidated by weighing out the sovereigns, which are coin equivalents of pounds sterling. It would have been manifestly impossible for European States and colonies to pay £100,000,000 in actual weight of gold in the year 1892. Had it been possible the United States could have made no use of the money except to spend it. Instruments of credit have done away with the necessity of handling coin to any considerable extent, or taking the risk of sending it long distances across the sea. When in the progress of time an international clearing house is established, the movement of coin will be less than it is now. In point of fact, the United States did spend a large part of the gold which was passed to their credit, and they strengthened their monetary position with the rest.

In another table are given the figures of our traffic with other countries. It will be observed that this traffic was with continents and countries from which our chief imports are derived. They are almost all non-machine using States, mainly in the tropical regions, and almost all making use of silver as the principal monetary metal. From this table it appears that we drew upon our gold balance to pay for our imports from these countries to the sum of $281,716,665. These figures are from the statistical abstract.

It is to be remarked that a slight change might be made on these figures, owing to a part of the imports from Brazil having been first recorded in depreciated paper money, while on the other hand the amounts of our exports to Mexico since the railway came into use have undoubtedly been considerably understated. These slight errors may be set off against each other.

The figures are sufficiently near to serve for the final statement, which may be given in the following terms: —

SUNDRY COUNTRIES IN ACCOUNT CURRENT WITH THE UNITED STATES, IN THE FISCAL YEAR, ENDING JUNE 30, 1892.

THE UNITED KINGDOM OF GREAT BRITAIN AND IRELAND.

	Debtor.	Creditor.	Debtor.	Creditor.
Dr. To exports mainly consisting of grain, provisions, dairy products, and cotton	$499,315,332			
Cr. By imports of miscellaneous goods	....	$156,300,861		
Balance at the credit of U. S. . .	....	....	....	$343,014,451

ALL OTHER EUROPEAN STATES.

Dr. To exports of provisions, oils., etc.	$351,010,717			
Cr. By imports of miscellaneous goods	....	$235,189,785		
Balance at the credit of U. S.	....	....	....	$115,811,932

CANADA AND OTHER COLONIES OR POSSESSIONS OF EUROPEAN STATES.

Dr. To exports	$80,986,077			
Cr. By imports	....	$54,806,407		
Balance at the credit of U. S.	....	....	....	$26,180,670
Total balance at the credit of U.S.	$931,313,026	$446,306,023		$485,006,933

THE CONTINENTS OF ASIA, AFRICA, SOUTH AND CENTRAL AMERICA, AUSTRALIA, MEXICO, WEST INDIES, ETC.

Dr. To exports	$99,547,102			
Cr. By imports	....	$357,721,059		
Balance at the debit of the U. S.	....	....	$276,173,957	
Final balance carried forward	....	....	208,832,996	
Dr. All countries to the U. S., $208,832,996				
Balance of trade, equivalent to £43,000,000	$1,030,860,128	$822,027,182	$485,006,953	$485,006,953

The imports and exports of gold and silver of the United States in the fiscal year 1892 balanced within less than $1,000,000, so that the above statement of the traffic of the United States for that year is in close approximation to the exact facts.

In that year the hard times in Europe caused by short crops, coupled with disasters in Australia and South America, together with a growing distrust of the intention of the United States to maintain the credit of the nation upon the gold standard of value, caused our creditors for capital lent us, especially in Great Britain, to dispose of many securities. This balance of our trade credit was doubtless applied in part to the reduction of our debt incurred for capital previously borrowed. The other part was applied to the payment of the expenses of our own citizens who dwell in Europe or who travel on letters of credit drawn on London. There are no data for an exact estimation of these expenditures. They have been roughly computed at $100,000,000 a year.

The goods which we imported in exchange for our exports were subjected to duties which yielded a revenue in that year of $177,452,964. This tax upon imports was either added to the price of the imported goods and paid by consumers or in a few instances it diminished the quantity of foreign goods which we should otherwise have received in exchange for our exports. We pay the tax in one way or the other.

Subsequently to the year ending June 30, 1892, distrust and panic arising from purely legislative causes, coupled with the disturbance of trade which always accompanies changes in the duties on imports, have caused great varia-

tions in the volume of our traffic. But these are mere temporary incidents. In the present year, 1894, our exports are again increasing, especially of manufactured products, while our imports have greatly diminished, and in addition to goods we have exported a large amount of our gold product and the whole product of our silver. It is now manifest that the credits to us on excess of merchandise only, exported in the fiscal year ending June 30, 1894, will exceed $250,000,000, or £50,000,000.

The rate of foreign exchange, however, again indicates that we are steadily reducing our permanent debt by the purchase of stocks or bonds now being sent home for sale. It is becoming more and more apparent that we have greatly diminished the debt negotiated for borrowed capital, and when confidence is restored the tide of capital may be reversed. We are becoming more and more creditors on our annual commerce in large but varying amounts. It is not probable that any similar panic to that which we have lately passed will occur again from similar causes. This severe lesson has sufficed. Every intelligent mechanic and artisan in the United States has already learned or is being made aware of the fact that since the resumption of specie payment on January 1, 1879, at the standard of the present lawful unit of value, a dollar made of gold, in which all the forms of money now in use are redeemable, the tendency of wages had been to advance and of prices to diminish.

Before this standard of value had been so uselessly imperilled in 1893, employment had been continuous throughout the two previous years; there had been no unwholesome speculation; business credits were upon a sound foundation; prices were low, but not as a rule so low as not to leave a fair margin of profit, and wages or earnings were higher than they ever had been before. The farmers, especially in the grain-growing States, who number in all about 4,500,000, had in the years succeeding the resumption of specie payments attained a condition of substantial prosperity. The reduction in the cost of their tools and supplies, and in the cost of distributing their products having more than counterbalanced the reduction in the price of their staple products, so as to enable them to increase crops in the face of declining prices, and also to reduce their indebtedness. In 1890, as I have elsewhere demonstrated from absolute data, the greater number of farms of the United States were in the possession of their owners free of any mortgage. The lesser portion were incumbered to less than half their true value, the general result being that the mortgage debt on true farms taken as a whole came to less than 10 per cent. of their value. Our farmers were and are now in a position to grant credit on their products, but they will insist that there shall be no doubt about the stability of the unit of value upon which their transactions are made. There never had been a period prior to 1892 in the history of the United States, or of any other country, when workmen had been enabled to secure to their own use and enjoyment so large and increasing a share of a constantly increasing product as in these two years, 1891 and 1892. The panic checked this progress and caused a considerable amount of compulsory idleness, which has been, in the judgment of the writer, greatly exaggerated. This panic set every one upon the line of investigation, and the more fully this work has been accomplished the more the craze for the free coinage of silver and for cheap fiat money has been exposed and stamped out. We have yet before us a difficult problem in settling the future conditions of

banking, but I think every doubt of the maintenance of the lawful unit of value, the gold dollar, has been removed — whatever may be the immediate condition of the discussion.

In order to comprehend the elements of our credit balance in the year ending June 30, 1892, attention must now be given to the kind and quality of our chief exports. These were as follows:

Breadstuffs	$299,363,117
Cotton	258,461,241
Cottonseed oil	4,982,285
Meat and dairy products	140,362,159
Animals	36,498,221
Tobacco	24,739,425
Total	$764,929,211

The lesser products of agriculture carried the amount to about $800,000,000, constituting 80 per cent. of the total export.

This classification is not, however, the same as that adopted in the United States census. In the latter all products of flour mills, of meat-packing establishments, of butter, cheese, and tobacco factories, and of canneries of meats, vegetables, and fruits are listed as manufactures. It is in this way that so great an apparent increase in manufactures has been disclosed.

Under the census classification our exports of the crude products of agriculture in their primary form amounted to a fraction over 55 per cent. of the whole, manufactures to a fraction under 40 per cent., mining and miscellaneous substantially 6 per cent., making a total of 100 in the present year. Under that classification the exports of manufactures and miscellaneous fabrics in the present fiscal year will exceed the export of the crude products of agriculture. We are gaining, especially in the higher types of manufactures of metal, of wood, of cotton fabrics, of leather and its manufactures, of agricultural implements, and miscellaneous goods of various kinds.

This exchange of product for product now takes the following triangular course. The United States supply Great Britain, the Netherlands, and Germany with food and with fibres which are by them converted into fabrics. Great Britain, the Netherlands, and Germany sell these finished fabrics to India, China, Africa, South and Central America. These countries — South America, China, India, Africa, Polynesia, and the West Indies — supply the United States with coffee, tea, sugar, wool, and other products of like kind, mainly materials for use in manufactures in their primary form — commonly called raw — or articles of food. The balances of this trade are settled in London in pounds sterling. It can hardly be conceived that the people of the United States, who are now granting credit to European States on which a gold balance is placed at their account ranging from three to five hundred million dollars a year or sixty to one hundred million pounds sterling, will now enter into any treaty by which European States may be able to convert their imports from us into finished fabrics, taking their pay from the non-machine using nations in silver, and then hold the power to pay over that silver to us without giving us any claim upon the gold if we want it. Could any people in possession of their senses make

such a treaty? Would not that be the effect of what is called a bi-metallic treaty? Is not a bi-metallic treaty merely one of alternate legal tender, under which the United States would be expected to give their debtors a choice between silver and gold, while depriving themselves of any right to say what kind of money they want?

The free commerce of Great Britain, her world-wide banking arrangements and the absolute stability of her unit of value, named a pound sterling, of 113 grains of gold, coupled with a national credit of permanent stability, have been among the principal causes of her paramount control of the commerce of the world. That stability of the unit of value in international commerce has been as great a benefit to the United States as to the people of Great Britain themselves.

I have said that these have been among the potent causes of the paramount control of commerce by Great Britain down to the present day; but underlying these causes there has been one other, perhaps more potent than either, namely, the dominion of Great Britain for nearly a century over the controlling supply of coal, iron, and steel. The dominating forces in commerce are food, fuel, iron, and copper. The portentous event of the present generation, which we are now witnessing, is the passing of that dominion of coal, iron, steel, and copper from Great Britain to the United States. But even this change in the situs of the chief production of coal and iron will be to the mutual advantage of both countries, when the English speaking people of the world are brought into the closest commercial union. The first steps in this direction have lately been taken.

The food which Great Britain wants can be produced in the United States with less effort or labor, and in greater abundance than anywhere else. Its production therefore yields the highest rates of wages or earnings, since these are the correlative of the low cost of labor.

Coal can be mined and coke can be made in greater abundance in the United States with less effort or labor than anywhere else. These products therefore yield the highest rate of wages, because high wages in money or what money will buy are the reflex of the low cost of production.

Iron and copper ores can be mined and converted in greater abundance with less effort or labor in the United States than anywhere else. Their production and conversion therefore yield the highest earnings, since these are the complement of the low cost of production.

Under a true commercial union these advantages of the English speaking people of the continent of America will be no more to the benefit of themselves than to the English speaking people of the United Kingdom. There will then be nominally two nations, but they will be practically one for commercial purposes. We will then constitute the only great body of people among the manufacturing or commercial States of the world whose people can produce food, fuel, iron, steel, and copper beyond their own present power of consumption, while the world wants the whole excess, and will pay for it in crude materials and tropical or semi-tropical products.

It should here be remarked that while Great Britain enjoys the advantage of free commerce with other countries, the United States enjoy the benefit of absolute free trade over a wider area and among a greater number of people

than has yet been secured elsewhere upon the globe. The people of Great Britain and of America are also alike free from military conscription.

The rule of blood and iron compels all the common people upon the continent of Europe to serve in destructive wars, or in yet more destructive preparation for war, by which they are themselves mutually oppressed, against their own will and to their own severe loss. These wars are incurred mainly to sustain dynasties and privileged classes that have ceased to justify their existence and are now obstructive to human liberty. Witness the grotesque absurdity of all these costly efforts in preparation for war. The people of nearly every country on the continent of Europe have been engaged in a war of tariffs, partly due to mutual repulsion, partly to conceal taxation by which the revenue is raised for sustaining armies, when the very armies themselves would not be required except for the maintenance of these tariff barriers to mutual service.

Upon the continent of America all the forces which are brought into action in our internal traffic are the solvents of race, creed, color, and condition. The annual traffic of the seven months in which the St. Mary's Canal that unites the great lakes above Detroit is open far exceeds the year's traffic through the Suez Canal. On the continent of Europe the forces in action serve to maintain the prejudices of race, creed, and condition, leading directly first to hunger and disease and then to socialism, anarchism, and nihilism. Each State tries to secure the control of the most effective killing machinery; then in grotesque absurdity each State tries to bring into existence the most effective Red Cross system for caring for the wounded. Each State tries to invent an impregnable shield for forts and ships of war, and then proceeds to waste more money in the effort to make irresistible guns and to invent explosives that will break the shields as fast as they are set up. Each State that has access to the sea exhausts its energies in building huge armored battle ships of such complexity that they may not even fire their guns in a peaceful review without becoming disabled, and cannot manœuvre except at the risk of sinking each other. States combine to prevent Russia gaining access to the Mediterranean lest she should become a great naval and commercial power, and in order to do so they keep back the progress of civilization by supporting the unspeakable Turk. All these cumbrous and costly ships are even now at the mercy of some simple device by which the first one that attacks any great harbor will probably be so surely and swiftly sunk as to forbid the expectation of ever bringing any crew, however brave, up to a second attack of the same kind.

The people of Great Britain are compelled to spend their resources in this manner in order to maintain an open way to their colonies and their dependencies in Asia and Africa, to whose people the English power and genius for administration is and always has been so great a blessing.

The people of the United States are free from the necessity of maintaining any great land or naval force. Our free commerce, each State with the other and presently with all the world, forbids the thought of any attack upon us. It is well assured that when it becomes necessary for us to fight for a principle we will fight to the end, but never for a mere trade policy.

We have lately wasted a good deal of money on one class of armored vessels of which the very title of "Commerce Destroyers" is a disgrace to ourselves. What could be more absurd than for us to prepare to destroy commerce when

the only countries that possess any commerce of any moment are our best customers, whose markets would be closed to our surplus products by the very contest in which these ships should be engaged? The time is near at hand, ay, it is at hand, when any provision for armed attack or defence among English speaking people is as absurd as it would now be useless and wicked.

The effect of the changes which are now coming into action, in the system of duties on imports in the United States will be beneficent and will lead rapidly, in my judgment, to further progress. The reduction of our duties on imports has been sincerely dreaded by the representatives of many important branches of industry, especially in the manufacture of textile fabrics, chemicals, glass, pottery, and in the conversion of crude materials into their higher forms. That fear has been honestly shared by a great many men in high public station who have no personal interest in any of these subjects. The support of the protective policy is and has been as honorable and sincere as that of its opponents. If it should happen, as I believe it will, that the progress of these very arts will be so much promoted by untaxing the crude materials that are used in them and thus removing the disparity in the cost of material which has been our principal disadvantage in our competition with other countries, it may follow that these very same manufacturers will cease to distrust our own power, and will no longer fear the competition of the underpaid and ill-fed workmen of the continent of Europe, to whom the term of pauper laborers has sometimes been applied. They may presently learn the truth of the aphorism, which, I believe, may be attributed to Mr. Gladstone, somewhat in these words — I quote from memory — "The road to free trade may be likened to the way to virtue; the first steps are the most painful, the last are the most profitable."

The present measure of tariff reform may be a very partial one, yet it works a greater change in the tariff of the United States than Sir Robert Peel's first measure of tariff reform of 1842 worked in the British system. When our surplus revenue again begins to accumulate, as it presently will, in ample measure to withdraw all our bonded or interest-bearing debt long before the last payment falls due in 1907, other great reductions in taxation may be anticipated. Our revenue from liquors and tobacco only, domestic and foreign, more than covers all the annual obligations of the general government except for pensions. The pension roll is rapidly diminishing, and has never been an important factor as a mere question of money. It is very different from the cost of an army. It is not the money cost of an army which bears with the worst effect upon the people; it is the withdrawal of men in the prime of life from the constructive duties of peace to the destructive purposes of war.

I do not claim that these views would have as yet the support of any very large number of persons in my own land, but they have the support of the few men of economic insight on whose judgment the greatest reliance may be placed. We must bear in mind that a century or a little more is a very short period in the upbuilding of a nation. The British, when, I believe, less than 8,000,000 in number, tried to cope with 3,000,000 or more of their own kind 3,000 miles away. It was an absurd effort, which leads one to respect the courage of the English nation more than its perception of its own power at that time. The Englishmen of a century ago were not very shrewd teachers, and our people were somewhat unwilling pupils in the art of trade isolation.

Through the efforts of their English rulers and fellow-subjects to restrict and absolutely control the trade and manufactures of the colonies of America our ancestors were forced to assert their independence.

At a little later period, when the textile industry was being developed, Englishmen tried to keep a monopoly of the manufacture, so that we were almost forced to retaliate by restrictions upon imports. I have read many letters of our engineers who crossed the Atlantic to get the first machinery for printing calicoes, when it was a penal offence to remove either the machines or the designs from British shores. Slater, the founder of cotton spinning in America, carried designs in his head that he did not dare to carry in his pocket.

Had the lesson that Adam Smith taught been learned by his compatriots in less than fifty years, there might have been no war of separation. Had they not claimed complete and absolute dominion over the open seas in 1812, there would have been no enforced embargo on trade in the United States, which gave the first stimulus to the manufactures that afterward claimed and secured a protective tariff. The war of 1812 was fought by the United States on the platform of free trade and sailors' rights.

When Great Britain began to leave off excessive protection in 1824 we began to increase it. People learn more quickly now than they did then, and our progress from this time, in comprehending the true sources of the wealth of nations, may be more rapid than theirs ever was.

We have established the single unit of value at the standard of gold, and it will be maintained. We have yet to adjust our banking system to new conditions. We have begun to remove all obstructions to international commerce by untaxing the materials of foreign origin which are necessary in the conduct of domestic manufactures. When the adjustment has been made to these new conditions, and when all the processes of manufacturing have been made free of taxation upon materials and machinery, we shall be ready to adjust duties on imports to the necessity of revenue only. No prudent Englishman would move faster or in any other way.

When that time presently arrives the English speaking people of Europe, of America, and of the Pacific islands, occupying the United States, Great Britain and Ireland, Canada, Australia, and New Zealand, with their kinsmen scattered all over the world, will be reunited in the bonds of mutual service. Great Britain and the United States will become even more the complements of each other than they are now. We may then carry good will and plenty to all races and conditions of men. That is the dream of peace of thinking men in my country.

I do not ignore the difficulties which have occurred, and which are not yet surmounted, growing out of the change of the ratio of silver to gold. They are comparable to other great changes that have occurred in the mechanism of production and distribution. When machinery displaces hand labor in any art the benefit to the multitude is gained at the cost of the few. There is a close analogy between this and the way in which gold has asserted its superiority as a unit of value. It is at the cost of temporary difficulties and losses to the few who are engaged in certain branches of commerce. But the evil is limited, the benefit is world wide. Had this not been so this change could not have occurred. It has come in spite of legislation, and not through the force or fiat of legislation.

In the same manner the centre of iron industry has moved to the United States. It matters not whether this change has been stimulated and hastened by a high tariff, or retarded. It has come, and that fact will have great influence on the future course of trade.

The first effect of removing obstructions to international commerce in the United States may be to the injury of many of the English metal and textile manufacturers. When the disparity in the cost of wool, of iron, and steel, and of a few other important articles has been removed by taking off the United States taxes, the manufacturers and metal workers of the United States will doubtless assume a larger share in building ships, machinery, agricultural implements, and the heavier and medium cotton fabrics, and probably many kinds of woollen goods, for other nations, in the supply of whose demand we have by our own acts heretofore left the English and the Germans in complete control. This will be but a temporary disadvantage to the few, and to the great advantage of the many in European countries. The general and final advantage of free commerce cannot fail to more than offset the temporary injury of a few special branches of industry, even if they are now among the most important.

Our dream is one of the peaceful control of the commerce of the world by the English speaking people. Who can compete with us when we are thus reunited? Will not the unspoken warning then be heard by all the oppressed inhabitants of the neighboring continents who are now burdened with the military system? DISARM OR STARVE.

THE EVIL EFFECT OF RAISING PRICES BY DEPRECIATING THE STANDARD OF VALUE. By EDWARD ATKINSON, Boston, Mass.

[ABSTRACT.]

ABOUT ten years since, I began an investigation on my own behalf in order to determine the effect of a depreciated currency upon the condition of working people, even when accompanied by rising wages. By working people I mean all that great class of people who depend for their daily bread substantially upon their daily earnings, whether secured on piece work, by day wages or salaries by the year — and who do not accumulate any large amount of capital in a lifetime.

It was believed by many during the greenback era in this country that the demand for labor which had arisen in the Northern States from the huge draft upon the working force for the conduct of the war itself, coupled with the war demand and waste of arms, ammunition, clothing, and food, had advanced wages in due proportion to the advance in prices and in the cost of living. Such was not the fact. The depreciation of the currency worked the same malignant influence that the enforced circulation of debased coin or depreciated money of full legal tender has invariably caused everywhere. It put great fortunes into the hands of the few at the cost of the many. The saying that "the rich grew richer because the poor became poorer" was then founded in fact. It now behooves the people of the United States not to permit the standard or unit of value to be again debased, else they will suffer again from a false distribution

of the products of labor. The money standard having been lost in the fluctuation of the legal currency between 1861 and 1879, it became necessary to establish another standard by which to measure the purchasing power of a day's work.

To that end I began my investigations into the customary expenditures of typical families for food, fuel, and clothing. I established certain fixed quantities of the principal elements of food, fuel, and materials for clothing, corresponding to the average consumption of adult members of the families of prosperous mechanics in the eastern and middle United States. I was obliged to take salted meats, in place of fresh meats, because the latter varied so greatly in price, according to the cut or part of the animal, but the staple kinds of salted meats served equally well as an element in the multiple standard. This standard was as follows:

ONE RATION.

	Per day.
½ to 1 pound meat, poultry or fish, varying according to kind and quality, costing on average	10c
½ to ⅔ pint of milk, 1 to 1½ ounce butter, ½ to ⅔ ounce cheese,	5c
1 egg every other day	½c
½ to 1 pound bread	2½c
Vegetables and roots	2a2½c
Sugar and syrup	2c
Tea and coffee	1c
Salt, spices, ice, and sundries	2a1½c
Total	25c

This customary day's ration I then converted into quantities corresponding to 400 days' rations, and I called that one year's supply of 365 days, with a margin over for contingencies. This gave me quantities to which I could easily apply prices.

Four hundred rations — 200 pounds corned beef, 100 pounds salt pork, 100 pounds smoked ham, 100 quarts milk, 30 pounds butter, 20 pounds cheese, 17 dozen eggs, 1 barrel flour, ½ barrel corn meal, 20 bushels potatoes, 80 pounds sugar, 4 pounds tea, 8 pounds coffee, $6 worth salt, spices, ice, and sundries, $100.

At the time my own inquiry was first made the above supply of food corresponded to the consumption of adults in and around Boston, and at the prices of the day it cost $100 or 25 cents each for 400 rations. In my study of the food question since that date these quantities have been verified. They allow for a large margin of customary waste.

The standard portion of clothing for one year was derived from the average of the annual consumption of cotton and woollen fabrics. It is substantially as follows:

Standard portion of cloth for one year — Ten yards medium brown cottons, 10 yards standard ginghams, 10 yards 36 inch bleached shirting, 20 yards printed calicoes, 10 yards 4 ounce woollen flannel or worsted dress goods, 5 yards 16 ounce cassimere, 5 yards Kentucky jeans, satinet, or light cassimere.

To this quantity of cloth I added two pairs of men's heavy boots, and as a standard of fuel one and one half tons of anthracite, or its equivalent in bituminous coal.

Having thus put together 400 portions of these necessaries of life, which correspond to 65 or 70 per cent. of the total expenditure per adult, I then secured as fully as I could the prices of these various articles in different places from 1860 to 1880, at periods five years apart. I had made fair progress in this investigation on my own behalf, when volume X of the census of 1880 was published.

This volume on prices and wages had been compiled by one of the most competent experts, Mr. Joseph D. Weeks. It gave retail prices in different parts of the country. I averaged the prices at ten large shops in the West and ten in the East. The results substantially concurred with my own figures previously obtained. I then averaged the wages of four classes of working people in one hundred factories and workshops, partly in the East and partly in the West. I then made a separate average of the wages or earnings of four classes.

No. 1 — Firemen, overseers, master mechanics, and men of special aptitude.

No. 2 — Carpenters, blacksmiths, masons, machinists, and other mechanics working in establishments of continuous occupation throughout the period.

No. 3 — Factory operatives in various branches of industry which are conducted on the collective method.

No. 4 — Common laborers.

Having ascertained from my own investigation and from Volume X. of the census what were the fair average daily earnings of each of these classes in continuous employment, I multiplied them by 300 days, corresponding to a year's continuous work. These tables gave me the standard earnings of these four classes in gold in 1860, in paper in 1865, 1870, and 1875, and again in gold in 1880. Subsequently I secured sufficient data from various sources to carry the figures forward to the year 1885.

I then applied the retail prices at the shops selected, averaging them to the multiple standard of quantities of food, fuel, and cloth, and in that way I deduced the purchasing power of a year's work of men and women in full occupation. I omitted rent because the charge for rent and the rental value of houses owned by occupants is subject to great variation as between city and country, between the East and the West, for climatic and other causes.

The publication of the report on prices and wages for fifty-two years on behalf of the finance committee of the Senate, compiled under the direction of Commissioner Carroll D. Wright, enabled me to verify all my previous tables, and to extend the analysis to the years 1890 and 1891 inclusive. All these several compilations — first my own; second, the figures published in Mr. Weeks' report, and third, those of Commissioner Wright's report, are so nearly concurrent as to prove that the margin of error is very small, and that it would not alter the final conclusion in any marked degree.

The general conclusion is that the purchasing power of wages has more than doubled in the United States in all classes since 1865. The purchasing power of wages was higher in 1860 on a gold standard of peace than on the paper standard of war in 1865.

For the purpose of illustrating this analysis in graphic form I have selected

class 2 — mechanics and artisans in continuous employment. This class represents a fair average of the community taken as a whole. Their wages correspond closely to the earnings of the great body of railway employees as well as many others. The earnings of this class have increased in purchasing power more than 75 per cent. since 1860 and more than 100 per cent. since 1865. I now submit a table which gives the facts in figures:

Year.	Kind of money.	One year's wages.	Price of uniform portions of the necessaries of life.	Portion which one year's earnings would pay for.	No. of persons who could be supplied.
1860	Gold	$468.00	30 95-100c.	$1,512.00	3.78
1865	Paper	702.00	55 69-100	1,261.00	3.15
1870	Paper	747.00	43 53-100	1,716.00	4.29
1875	Paper	687.00	38 69-100	1,776.00	4.44
1880	Gold	678.00	33 24-100	2,040.00	5 01
1885	Gold	720.00	30	2,400.00	6.
1890–1 . . .	Gold	776.00	29	2,676.00	6.69

The changing relations of these several factors is shown in the subsequent graphical form, of which one example will suffice. I have also applied the same method of analysis to the men, women, and children who are occupied in a single textile factory, averaging them all, and then taking the prices in the town in which that factory was situated. I have also analyzed one great railway system, employing eleven different classes of men. I have put all these classes together in one table and compared the results by taking prices at the central point of that system. In every instance the results correspond and the graphical image is substantially the same with the one now submitted.

These examples need to be very carefully considered by every person who is inclined to support an increase in the volume of money in the expectation of maintaining or raising prices by monetary legislation.

The pretext on which the unlimited issue of flat money was advocated by the greenback party of 1874 was the same as the argument lately presented for the free coinage of silver by the representatives of the mining camps in Congress. It is the same as the argument on which the Populists now demand the issue of legal tender paper money at the rate of $50, more or less, per head of population. The objective point of the advocates of an international treaty of bi-metallism, which means a treaty of alternate legal tender, is either to raise prices or to maintain prices, or to prevent the further progress of the so-called fatal fall of prices by monetary legislation and the enforced use of flat money.

All the advocates of these several different monetary hypotheses appear to be either ignorant of the relation of prices to wages, or else they disregard the acts, or else they shut their eyes to the past and present conditions, and refuse o answer questions when brought to an issue on the matter.

The facts are disclosed by the figures in the diagrams; they are made manifest to the eye so that he who runs may read.

In order that these tables may not stand on my sole authority, and in order that I may not be charged with any selection of figures to prove my own case, I have added an additional graphical table for which all the figures are derived from the digest of Commissioner Wright's report, the authority of which has never yet been questioned. I have merely put these figures into a graphical form corresponding to the facts that are given in the digest by Professor R. P. Falkner, Commissioner Wright's most able assistant.

It may be remarked that the advocates of the so-called bi-metallic treaty date the alleged fall in prices from the year 1873, apparently choosing that date because it is the year in which certain action was taken in Germany and in the United States to displace silver coin from its full legal tender function while continuing the monetary use of silver as a subsidiary coinage. It might well be asked why these gentlemen did not go back to an earlier date when the average prices of the necessaries of life were higher than in 1873. Eighteen hundred and sixty-six would have been a much more suitable date. Even the gold prices of the necessaries of life were much higher at that date than in 1873.

The downward trend of prices began before the alleged demonetization of silver by Germany, but there has been no general or uniform fall in prices of goods corresponding to the uniform fall or depreciation in the price of silver. The price of a few important articles has risen since 1873. Many have varied but little from the standard of 1870 to 1875. The prices of many other articles of more abundant production to which science and invention have been most fully applied, coupled with the very much lessened cost of distribution, have fallen more than the fall in silver. The general trend of prices has been downward since 1866. In 1870 we had surmounted some of the evil influences of the war.

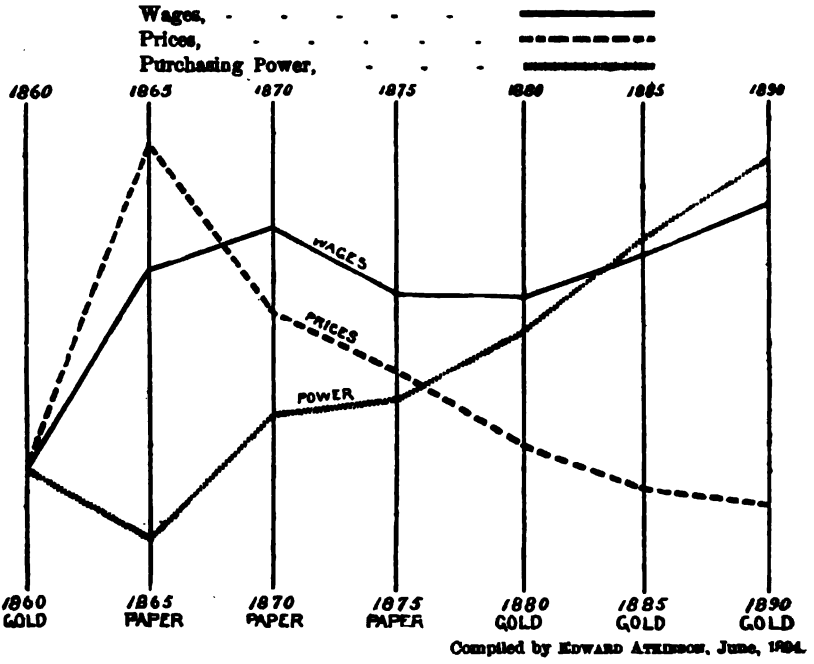
I have, therefore, taken 1870 as the starting point on a unit of one hundred. I then give the average of prices, wages, and purchasing power from 1850 to 1890 inclusive, at intervals five years apart.

The evil effect of the depreciation of the legal tender notes known as greenbacks, which were issued during the civil war for the purpose of collecting a forced loan, was greatly obscured during that war by the excessive demand for food material and many other articles, which demand was brought into force by the war itself. Moreover, the effect of withdrawing the great body of men from the fields, from the workshops and from the factories for service in the army rendered labor scarce, but it also gave a great incentive to invention. The product of the country was actually increased in that period, and there was great activity in trade as well as obnoxious speculation induced by the depreciation of the currency, up to the culminating point in 1870. Those war fortunes are among the subtle causes of the prejudice against capitalists.

At that date, 1870, financial sanity began to be restored, and after that date there was steady progress toward normal conditions, although excessive railway construction did not culminate until a later period.

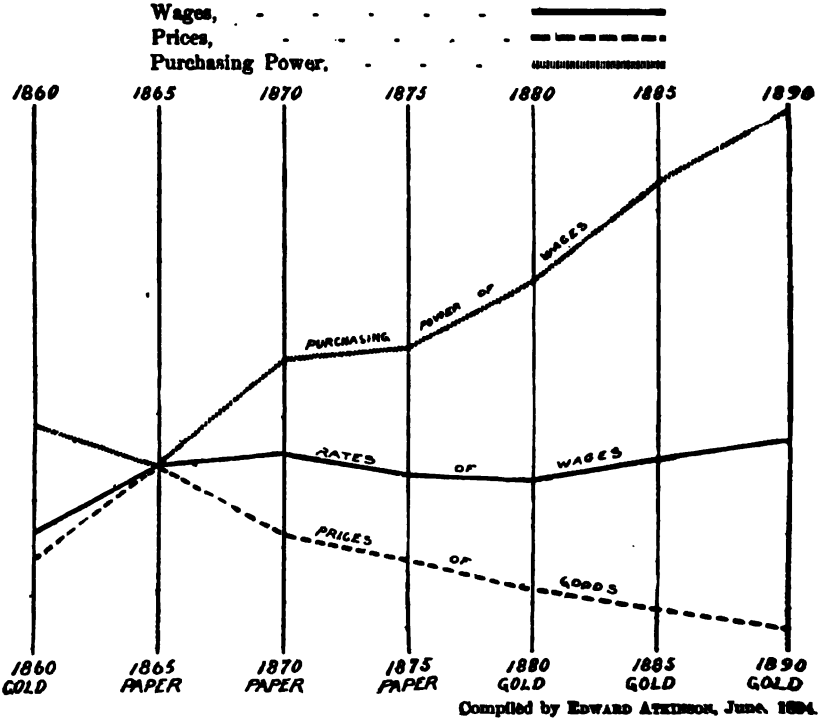
In the interval between 1870 and 1879 there were, of course, a great many hardships which were unavoidable. As soon as the specie standard was restored by

VARIATION IN WAGES, PRICES AND THE PURCHASING POWER OF WAGES IN UNIFORM PORTION OF FOOD, FUEL AND MATERIAL FOR CLOTHING AT THEIR RATIO TO EACH OTHER IN 1860.



Compiled by EDWARD ATKINSON, June, 1894.

VARIATION IN WAGES, PRICES AND THE PURCHASING POWER OF WAGES IN UNIFORM PORTION OF FOOD, FUEL AND MATERIAL FOR CLOTHING AT THEIR RATIO TO EACH OTHER IN 1865.



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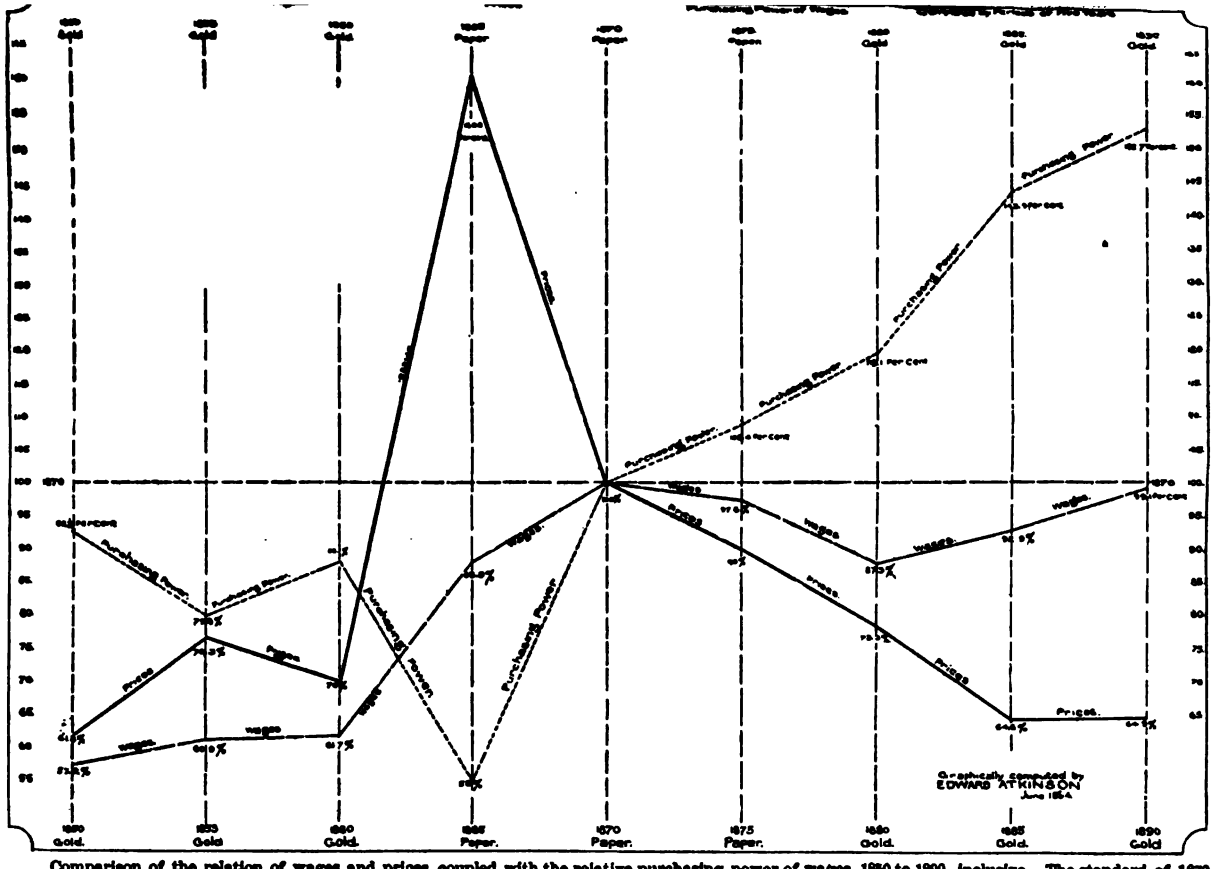


(426)

Comparison of the relation of wages and prices, coupled with the relative purchasing power of wages, 1860 to 1890, inclusive. The standard of 1870 being taken at 100 on the three elements, the variations are from that initial point.

The data for the table are taken wholly from the Senate Report on Prices and Wages for 52 years, compiled under the direction of Commissioner Carroll D. Wright. The digest of these statistics was made by Prof. Roland P. Falkner. The wages are computed on all industries covered in the report. See Vol. I., page 174. The prices are on all articles treated in the report averaged by Prof. Falkner according to the relative importance in consumption. See Vol. I., page 98. The initial point taken at 100 by Prof. Falkner is 1860. I have changed the initial point to 1870, and the line of purchasing power of wages dates from that year when the Civil War had been over more than five years and measures for restoring the specie standard on a gold basis had begun.

the nation, January 1, 1879, progress on a sound foundation went on with renewed activity and energy. Prices diminished through the rapid extension and application of improvements in the methods of production and distribution, still leaving a normal but diminishing profit in every branch of industry except those which had been adversely affected by an excessive tariff. Wages steadily advanced, and these favorable conditions continued down to the beginning of the year 1893. The forces making for progress delayed the effect of the attacks on the standard of value until the early part of that year.

Two or three years ago the writer was asked what would be the end of the purchase of silver bullion by the treasury of the United States and the threat of the free coinage of silver, to which he replied that "it would be a financial crisis such as we had seldom if ever seen before, and a complete paralysis of industry." To the question when, his reply was: "Whenever the mass of the people comprehend the danger; whenever that time comes, the purchase of silver will be stopped and the unit of value will be maintained, cost what it may."

That time was reached in April, 1893, and the prediction was verified. The subsequent recurrence of these threats of debasement of the monetary standard from time to time, and the distrust thereby caused, coupled with the effect which always accompanies great changes in the collection of revenue by duties on imports have brought about the conditions in which the people of the United States now find themselves.

We are smothered in the abundance of our own products; we are burdened with an excess of all the necessaries of life; we are furnished with more than adequate means of transportation; yet want exists in the midst of plenty, while incapacity rules in the halls of Congress.

The safety of the country rests for the time being upon the courage of the executive officers of the nation, who have justified the confidence which has been so fully reposed in them.

Slowly but surely the mass of the people are learning the lesson. Public opinion is becoming enlightened, so that the end of this purely political and non-commercial crisis can be foreseen at an early day.

[These papers were prepared with a view to being read at the meeting of the British Association as well as at the American Association for the Advancement of Science.

The time of the section having been fully assigned, only one paper could be read at the British Association, for which reason the second only was submitted.]

TEACHING DOMESTIC SCIENCE IN AN AGRICULTURAL COLLEGE. By Mrs. NELLIE S. KEDZIE, Professor of Household Economy and Hygiene, State Agricultural College, Manhattan, Kansas.

THE Handbook of the Agricultural College of Kansas, printed in 1874, makes the assertion that "A girl has a right to an education as precisely adapted to a woman's work as is a boy's preparatory to a man's work."

The realization of that thought marks the beginning of Domestic Science in that Institution. It is true the beginning was very small — being only a sew-

ing machine placed upon one corner of the chapel platform, and a woman, competent to teach the few girls assigned to her care, the art of sewing. But with even this small beginning, a cause so full of right grew almost without care.

The needs of a woman's life for some education which would give her power over the duties that came into her womanly hand, became more and more apparent. The fact was recognized, that every woman, whatever her calling, whatever her position in life, needs to know the use of a needle — needs to know how to cook and to serve food. For only intelligent sewing and cooking will bring the best results into family life. Only intelligent guiding will demand good service, and will produce efficient servants.

Twenty years of growth, twenty years of experience, have given Domestic Science in the Kansas Agricultural College an equal place with other branches of science, and the department to-day stands for the helping of girls to grow into the earnest helpful women who will make homes such as are needed in every State of this Union.

Recognizing the truth of Ruskin's statement that "there can be no happy labor without thought, and no healthy thought without labor," that the two must go together, every student in this College must use his hands in some kind of manual training one hour every day. Not for learning a trade, not for proficiency in any one line, but for manual dexterity, that the hands may be always ready to follow the leading of the brain, and that "to will" is always to be followed by "to do."

The college course is four years. During her first year, every girl is required to take her "Industrial" one hour each day in the sewing room for one term. During the second year, she has one term of "Industrial" in the "Kitchen Laboratory," and one term in the "Dairy," while the remaining nine terms of the four years' course, she may choose her "Industrial" and may take sewing or cooking, instrumental music, printing or floriculture.

It must be some handwork which will keep her hands supple and willing to follow the dictation of her brain.

The sewing began with one machine. To-day the light, cheery, well-furnished sewing rooms contain nine machines, beside cutting tables, work tables, chests and lockers for work, pressing tables with gas heaters, and large mirrors.

A glass case holds a few specimen pieces of sewing, which are kept for exhibit. There are also wardrobes, where hide the pretty gowns that are growing under skilled fingers, and that will soon adorn the makers who are members of the sewing class.

Each girl is taught to do the plain sewing which is needed by every hand, is given tasks of learning the various stitches, and then is given a plain garment to make. As she becomes competent, she is taught the manipulation of a machine, and the cutting and fitting of garments. She may learn the art of dressmaking if she choose, and must design trimmings as well as fashions for the making of garments.

Every student may bring her own material and may make for herself any garments she wishes, as fast as she is, in the opinion of the teacher, competent. Fancy work is not omitted, and about Christmas time there is an array of dainty gifts designed for the dear home-folks, executed by deft fingers which are guided by loving thought.

Nearly all the girl graduates take pride in the fact that their graduating dresses are entirely the work of their own hands under the guidance of the efficient teacher of sewing.

The other department of Domestic Science, Household Economy, may appeal more strongly to the general public because of its more direct influence on the race; still, while we all know that whatsoever a man shall eat, so shall his work and his life be, the effect of suitable garments is not to be ignored, and the moral effect of well-made clothing, as well as the wholesome American independence from the despotic sway of the dressmaker gives to every girl an added dignity in the consciousness of her own power. So we hold both branches of Domestic Science to be of importance.

The Household Economy comes during the second year, after one term in Chemistry. The teaching is done by means of lectures every day, and these continue one term. These lectures treat of the production, the preparation, the true food value, the buying, the cooking, and the serving of foods. During this term every member of this class takes her Industrial in the Kitchen Laboratory, which is furnished with two ranges and an Aladdin oven, cooking tables, hot and cold water, cupboards, chests, and pantries sufficient to contain all the utensils used by the classes. There at her own table she cooks the food the lecture has described, and with her own hands prepares it for the table. In this way the work of the term is devoted to the actual learning to cook.

There are no dormitories or boarding halls on the campus, so the food is disposed of at a small price in this way: On Monday a dinner is prepared by the class. Covers are laid for about twenty guests, and while post graduate students perform the duties of host and hostess, two or three members of the class serve the dinner. In no better way can the duties of host, hostess, and waitress be learned. Members of the Faculty pay twenty cents each, eating steadily through the three or four courses, and the interest in the dinner is always new because it is always cooked and served by a new division of the class.

On Wednesday a simple hot lunch is served to the members of the senior class, and on Friday comes a lunch which is partaken of by any one who holds a ticket.

On Thursday as many tickets are sold as the condition of the larder will permit. The owner of a ticket obtains on Friday a plate of lunch and a cup of hot coffee. All these lunches are sold at the uniform price of ten cents, which nearly covers the cost of materials.

This disposal of food gives an opportunity for each member of the class to cook an amount such as would be made in an ordinary family, and the fact that classmates and friends will partake of the food gives greater interest to its preparation. The lessons are not tasks, but are pleasures which bring with themselves thoughts of coming times when "the proof of the pudding shall be in the eating of it."

In this way the substantial cooking is taught; every girl must at least twice make bread and biscuits, cook steak and roast, make soup, make pies, puddings, and cake, while a very little of the work in salads, dainty desserts, creams, and ices may come in.

This work continues through the winter and spring terms, being varied during the latter term by having one division of the class in turn attend to the dairy

work. The milk is skimmed, the cream churned, the butter washed, salted, worked, printed, and about thirty pounds per week made ready for market. Two or three cheeses are made during the term, and cottage cheese is a weekly dish.

During the term this class is studying Botany or Entomology, and must make their collections. So, many a picnic lunch is planned, cooked, and packed by these girls, who combine Geometry and Entomolgy with their Cooking and Rhetoric — and who do them all well.

A party is planned for this term to which their classmates, the young men, are invited, and the cooking is all done by the class girls in class hours.

Needless to say, the second-year girls are favorites in their class!

During the third and fourth years many young women choose cooking as their Industrial. They have already had the two terms of second-year work. Their work begins with canning and preserving fruit. They make jellies and pickles, catsups and sauces. When the season for fruits is over they begin on fancy breads.

Then they take up meats, having an ox cut up before them that they may know where to find the various cuts, and they learn, not only the market name for each piece, but the best way to cook that piece in order to make it most nutritious and most palatable. While working under the general subject of meats, soups, fish, shellfish, and eggs have their share of attention, and then the salads, pastries, cakes, desserts of all kinds follow in their order. As fast as one subject is mastered, another is begun until the art of cooking becomes a pleasure because easily accomplished.

During the year the class plans, cooks, and serves a breakfast, a dinner, and a tea for the faculty, their wives, and the Regents, numbering about fifty people. The tables are set and decorated by the class. All the food is prepared by them, and these meals are as well managed as any meal need be in any home for any guest.

This class also holds an occasional reception, to which the seniors are invited. Certain members receive the guests, others preside at the tea or the chocolate table, while the remaining members of the class act as assistants to the hostess, thus gaining in responsibility, and learning the best of lessons in helping some guest to spend a happy hour.

Along with the practical part of this work these advanced pupils must read up on certain subjects in order, and write essays giving their knowledge of food stuffs, the values of certain foods for certain kinds of work, and for the different seasons of the year.

They must make out lists of menus for families in varying kinds of work and for warm and cold weather, making with these menus estimates of the cost of each meal.

During the spring term of the year the third-year young women are studying Hygiene, and some attention is paid to the preparation of food for the sick.

Along with learning to cook the food comes familiarity with the many labor-saving devices with which the kitchen of to-day needs to be furnished, and becoming accustomed to their use, when the time comes to furnish her own kitchen, a girl knows what she wants to put into that all-important room. After graduation, if a young woman wishes to perfect herself in this work, she

comes back and takes a two years' course of work in which chemistry and cooking are combined, where she is taught to think out, and then to work out, many of the problems of nutrition, of the economies of the household, and the need for thought in regard to food.

The equipment of this Department of Domestic Science is at present $1500. The sewing-rooms have $700, and they accommodate about one hundred girls each term. The kitchen laboratory has $650, and the dairy $150.

The cost of running the sewing department is merely nominal, as most of the students bring their own garments to make. Last year there were in the kitchen laboratory one hundred and seventeen students during the three terms; $415.00 were expended for materials for cooking, and $350.00 were taken in for lunches and food sold, making the department cost the college about $65.00 for the year.

We are told that 90 % of the homes of this country have their household work done by members of the family. Can there be any more important line of study for the young women of the land than this, which teaches them to be wise rulers over their own dominion? The few who belong to the 10 % who will hire servants will make better mistresses, and will have less anxiety over the never-settled servant-girl question if they know how work should be performed.

In this day, which has given into the hands of women so many duties of so many kinds, if all the duties are to be performed, women must have special provision for help in some direction.

There can be no better help than making them competent to do the essential work — the home duties — in the best and easiest possible way.

Give them ability to carry along the home work with ease, and the duties of church, society, self-culture, will not crowd out the home, but will make it stronger and better because of contact with the outer world.

This one Agricultural College is one of many where work in Domestic Science is as much a part of the course of study for the girls as is agriculture for the boys.

When the boys learn to grow wheat, the girls learn to make it into bread; when the boys raise apples, the girls give them pie.

And so both sides of the house shall be trained until the perfect home shall be attained, and every woman will "look well to the ways of her household," because she is an expert in the line of Domestic Science.

A STUDY IN SOCIAL ECONOMY. By Mrs. LAURA TALBOTT, 927 P Street, Washington, D. C.

[ABSTRACT.]

IN 1870 the population of Washington was 109,000; by the census of 1890 the figures are 229,000, an increase of more than double in twenty years.

The limits of the city during that time have been greatly extended, both into the country and by reclaiming the flats, where there are great possibilities for a beautiful park like the embankment of the Thames in London.

Attracted by the beauty and healthfulness as well as by the social and literary

advantages to be enjoyed by themselves and by their children, crowds of people are coming to Washington to reside, bringing with them much wealth and culture.

Notwithstanding the evident improvement of the national capital in many respects, still there are numerous and deplorable defects, thus presenting to the eyes of intelligent foreigners the aspect of various elements of the highest enlightenment in combination with elements of barbarism.

Not to speak of the corruptions of politics, which have a most evil effect upon the tone of society in general, not to speak of the depraved as well as the frivolous conditions of society existing, there is much beside to be deplored in the social and sanitary condition of our charming city, towards which the people of the whole country seem to turn with eyes full of pleasure and delight, as should be the case with the capital of the nation.

The public schools are carrying on their machinery after the commonly approved manner, fine buildings have been erected in various parts of the city, conscientious teachers are hard at work, trying to do their duty, and about 40,000 children are annually seated during school hours in the capital city. This is all very well as far as it goes, but there is an element in the city which is a relic of barbarism and a source of danger to the body politic; so long as a human life is permitted to enter into life in society, and evolve its being without let or hindrance, growing to manhood and womanhood with all its inheritance of ignorance and vicious nature uncontrolled, so long will our annals be filled with police reports of crime and wickedness which infest our city. Is it not strange when so much has been done to fit the children of intelligent people for society and for business, that no attention whatever has been given to the ragged element which crowds our streets and faces us at every corner, an element disorderly and dangerous in the extreme? Many philanthropic attempts have been made to do something for this class, but not much has been accomplished, nor will be till properly conducted Kindergartens and Manual Training schools after the manner of those in Belgium are established in connection with the public schools, as a preventive method of treating vagrants.

One attempt to help this class was made by the establishment of Night Schools, a movement in which Mrs. Darwin R. James of Brooklyn took such a warm interest, and by the aid of Mr. James, who was congressman at that time, Congress was induced to appropriate $5,000 annually, but $40,000 was really needed in order to establish Manual Training schools.

The evolution of the night schools was interesting in one respect, as it gave evidence of the ignorance existing among our "powers that be" of the needs of the people. About six years ago, a colored sewing girl remarked that she would like to attend school, and she would willingly give fifty cents a month to go two or three times a week to night school. Upon inquiry, it was found that no free night schools were in existence in the city, nor was there any likelihood of there being any started at public expense. The trustees were invited to meet a committee of ladies at the residence of Mrs. Darwin R. James, and four persons responded, one of them being a trustee of the public schools. At first, he said the people neither wanted nor needed night schools, and they would be a failure. However, he listened to the arguments presented to show that the Knights of Labor and others had petitioned for night schools for several successive years, yet

no attention was paid to these petitions of the public. It was decided then that if the people wished to show their desire for night schools, it would be best to place blank books at the Sumner, and also at the Franklin Building, and advertise in the press that the books were open for signatures of those persons desirous of attending free night schools. By the first of October, fourteen hundred names had been registered. At a meeting of the trustees, rooms and light were promised, but there was no money for salaries of the teachers. Three hundred dollars were pledged by the committee until Congress should convene in December. The night schools were opened in November, the seats were filled, and great enthusiasm was manifested by the pupils, who were of all ages. Unfortunately, the trustees were divided among themselves that winter, and the board was dissolved, and the committee of ladies were left with the night schools on their hands. By Easter the debt had increased to a little over a thousand dollars, and no signs of aid from Congress, much less from the trustees. Frederick Douglass gave a lecture, and Prof. Simon Newcomb another, which assisted by the sum of two hundred dollars to pay the teachers, but it was not until the following September, and after very great effort on the part of Congressman James that the teachers received the balance of their salaries, which amounted to six hundred dollars. This experiment was sufficient to open the eyes and ears of Congress, and since then there has been an annual appropriation of $5,000 for the night schools in the city of Washington. But just here is a point to be noted, which shows whereby the original motive of the movement was set aside. At first the night schools were attended by pupils of all ages, particularly by the old slaves, who would walk two or more miles on cold winter nights, if they might but have a chance to learn to read their Bible, or a letter from a distant son or daughter. Their interest was intense, and Mrs. James and others visited the night schools and talked with these older people, the relics of slavery, some of whose backs showed the hard ridges of the slave-master's whip.

At the end of the year, a rule was passed that no one over forty years of age should be permitted to attend the night schools. Another line of work was soon developed for the use of the money. High schools and business schools were opened at night, and young men and women, amply able in many cases to pay for their tuition, were admitted free to the best advantages the public schools afford; but not only that: but intelligent foreigners, clerks in our departments, at a salary of over a thousand dollars a year, were urged to and did attend the free classes in Latin at the night schools, thereby shutting out from the blessings of a common school hundreds of colored youth that apply every fall and receive the answer, "There are no seats." It is plain to be seen that there is no room in the ordinary day or night public school for the vagrants who grow up to fill our almshouses and our jails.

The need of the lowest elements of society should be watched and guarded, just as we guard against any pests in our houses, and not one should be left to blossom into crime and anarchy.

It is a fact that some little colored boys who carried baskets at market or blacked shoes were given some lessons in carpentering and shoemaking, by the assistance of an old Friend. As the result of that slight help, you will find little carpenter shops at various points in the back alleys in Washington, where some

of these pupils are now supporting families by making and selling clothes-bars, benches, which they learned to make while attending the manual training class of Prof. W. F. Mitchell. It is also a fact that when no more lessons could be arranged for with Professor Mitchell, that often the committee would be besieged by dozens of colored boys, between ten and fifteen years of age, to open the carpentering or tailoring shop again, but it has never been done, chiefly for the lack of means. Here would be a satisfactory way to solve the Negro Problem by establishing a manual training school for those children who cannot attend the ordinary public schools.

Would not taxpayers be justified in demanding that their burdens should be better adjusted by establishing institutions calculated to prevent crime, rather than supporting such a magnitude of machinery of police courts, jails, etc. We certainly need some kind of schools for preventive work among the vagrant children in Washington, that they may be assisted to become useful citizens instead of burdens upon society. The expense would then be one dollar where it is now ten in expenditure for police machinery. To be practical, I have here a plan for an industrial school for vagrant children that is intended to develop their good and destroy their bad tendencies. Every step in the scheme is intended to be philosophical, and to give the best development possible to a child of the lowest classes. The idea of reform school does not enter into this study of vagrants, for that belongs to the Court for the Administration of Justice, of which Attorney-General Olney is the head. Our plan is for the infant, and fresh young mind, just emerging into life, which has no natural guides, and therefore such guides and helps should be furnished by Congress in order to fit the child for its position on a level with people of refinement and good character.

THE EVOLUTION OF A COOKING SCHOOL IN WASHINGTON, D. C. By Mrs. LAURA OSBORN TALBOTT, 927 P. Street, Washington, D. C.

[ABSTRACT.]

IT is well known of what recent date teaching of cooking has been considered a necessary part of the education of our young people. Twenty years ago the idea was unthought of. Now cooking is a part of the system of the public schools in Washington, and in every way successful, and all doubt of its usefulness is fast vanishing from the minds of its early antagonists.

The beginning of cooking schools was in the establishment of a mission school of cookery eighteen years ago. The first class consisted of six little colored girls, which was soon followed by larger classes, and after many invitations sent to pupils of the public schools, at last, about five years ago, the trustees of public schools in Washington permitted five classes of white girls to attend the cooking school, each class attending successive days two hours at a time, receiving free instruction from an expert teacher, with free use of materials.

One of the teachers employed was a graduate of the Kensington School of Cookery, London, England, and private lessons were given at moderate price, which assisted some in support of the free classes; however, many thousands

of dollars have been furnished by the founder of the school, Mrs. Anna Lowell Woodbury and other friends.

The struggle to convert public opinion, as well as the directors of the public schools, as to the feasibility of teaching cooking, was long and severe, but at last they are firmly established.

The mission school still continues its beneficent work among both white and colored, as there are always children who cannot attend the public schools. The children attend regularly, and their homes give evidence of benefits received from the cooking school.

The school has given instruction to more than seventeen hundred girls, and has had about two hundred and fifty in the normal classes. All teachers are now fitted in the pay school, and pay a moderate price to cover expenses. Young women from New Hampshire and elsewhere attended the last year.

Several thousand girls have received instruction in cooking in the public school, and the fear that certain obstacles might arise to injure the success of the movement has been dissipated.

The mission school has thus helped to introduce cooking into the public schools, and has established a normal institute for training teachers of cooking, and it is intended to make it a Memorial to the Nurses of the late war who were connected with the *Diet Kitchen*.

RADICAL DEFECTS IN MUNICIPAL FIRE DEPARTMENTS. By LAURA OSBORG TALBOTT, 927 P. Street, Washington, D. C.

[ABSTRACT.]

I. Important position of the fire department in every municipality.
II. Admitted fine condition of engine and horses, and ability of the men.
III. The defects in the system as to providing protective clothes of asbestos material for the men, also asbestos ropes.
IV. Inadequate pay of firemen.
V. Necessity for fire inquests.

TESTS OF STABILITY IN THE VALUE OF MONEY. By E. T. PETERS, Box 265, Washington, D. C.

[ABSTRACT.]

THE arguments of unconditional bi-metallists on the one hand, and those often used by gold-monometallists on the other, imply a belief in two different standards of value, one of which may be called the "goods standard," and the other the "labor standard." In point of fact, value depends on human estimation of things, and there is no assurance that human estimation of a given quantity of goods, or a given quantity of labor, will remain unchanged for one day, to say nothing of doing so through periods comprising a considerable number of years.

In a stationary condition of industry the two standards mentioned might coincide, and both might coincide with a just standard of value. In a progres-

sive condition of industry, like that of the present age, either the goods standard, or the labor standard, might coincide with a just standard of value under conceivable conditions, but the conditions which would require the one would exclude the other.

If the craving for goods increased as rapidly as the productivity of labor, so that to satisfy the demand for comfort, luxury, ostentation, or what not, it was necessary to work just as hard and just as much as if no increase had taken place in the productivity of labor; and if the general feelings of men towards goods on one side, and labor on the other, were such that they voluntarily chose so to do, the labor standard would then coincide with a just standard of value. Under such conditions a creditor might justly refuse to be content with receiving from his debtor the quantity of goods represented by his loan when made, on the ground that that quantity of goods no longer corresponded to the intensity of desire for goods, and that they, therefore, represented a lower degree of satisfaction. And he might fairly claim that to get the same degree of satisfaction represented by his loan when made, he must receive a considerably larger quantity of goods than the loan then represented. On the other hand, the debtor would have no just ground of complaint at having to perform, — in order to get this increased quantity of goods, — just as much labor as was represented by the loan when he obtained it; for though it is true that by our hypothesis, labor has become more effective in producing goods, it has not become more effective in satisfying human cravings for goods. Moreover, by the same hypothesis, there has been no increase in the general aversion to labor, so that in performing the amount of labor represented by the loan when made, he is subjected to no hardship. The creditor receives only the same degree of satisfaction, and the debtor makes only the same amount of sacrifice, that the loan originally represented.

Let us, however, suppose that human feeling takes a quite different course; that instead of an increase in the craving for goods taking place, a wave of educational enthusiasm, for example, sweeps over the community, and with it an intense craving for increased leisure, to be used for non-economic purposes. We may suppose that the entire advantage resulting from the increased productivity of labor is taken in the form of this increased leisure, and that there is no increase in the consumption of goods, people having adopted as their practical guide, the motto of plain living and high thinking. Under such conditions the craving for goods will be satisfied as easily as it was before the increase in the productivity of labor, and our supposed creditor, in receiving from his debtor a quantity of goods equal to that represented by the loan when made, will also receive a degree of satisfaction equal to that then represented by the same loan. Nor will he have cause to complain because the debtor is able to procure that quantity of goods, and thus to cancel his obligation, with a diminished quantity of labor. By our hypothesis, it has become customary throughout the community to perform a diminished amount of labor, the aversion to labor having increased with the increased craving for leisure for non-economic purposes. To exact of the debtor under these conditions the quantity of labor originally represented by the loan, would be to exact from him a decidedly greater sacrifice than that so represented. That amount of sacrifice is in fact fully contained in the diminished amount of labor, which, by our hypothesis, has now become

customary. In short, under the conditions contemplated by this hypothesis, a goods standard is a just standard, the creditor in receiving an equal quantity of goods, receiving an equal satisfaction, and the debtor, in performing a diminished amount of labor, making an equal amount of sacrifice.

We might have pushed our supposition still further in each direction, and might have supposed conditions under which the creditor could justly claim an increase in the quantity of goods returned to him more than proportional to the increase in the productivity of labor, or under which the debtor might justly claim to satisfy his obligation with an amount of labor diminished more than proportionally to the increase in its productivity. But even our original supposition was an extreme one. As a matter of practical experience, it is reasonably sure to happen that as the productivity of labor increases, a part of the advantage resulting from its increase will be taken in the form of increased consumption of goods, while another part is taken in the form of increased leisure. And when the course of human feeling with reference to goods on the one hand and labor on the other is of this character, a standard of value which results in giving to the creditor a somewhat increased amount of goods, and exacting from the debtor a somewhat diminished amount of labor, would be a just standard. In ordinary experience it probably would not be far from the mark if our standard were of such a character as to divide the results of industrial progress about equally between the debtor and the creditor; but from the point of view of economic theory, there is no assurance that this would be the case. All would depend on the course of human feeling in the premises.

Theoretical completeness would require us to consider a condition of industrial retrogression, and such a condition might be treated in much the same manner in which we have already treated the condition of industrial progress that corresponds to our actual experience at the present day.

A MISLEADING STATEMENT OF GRESHAM'S LAW. By E. T. PETERS, Washington, D. C.

[ABSTRACT.]

THE observed fact of monetary circulation known as "Gresham's Law" is often loosely stated as being that bad money drives good money, or that an inferior money drives a better money, out of circulation. This form of statement has no doubt had its origin in the fact that one of the most familiar instances of the actual operation of the law in question is that in which worn or debased coins expel from circulation those of full legal weight, whenever the total quantity of money is such that the resulting level of prices makes those perfect coins worth more as bullion than they are worth as money.

The economic law with which the name of Sir Thomas Gresham has become identified of course is: that when any part of the money in circulation becomes worth more as an article of commerce than the amount for which it is a legal tender in paying debts or making purchases, it becomes the interest of those who handle money in considerable quantities to separate this money from the less valuable money with which it circulates in common, and dispose of it to

the exporter or the melter, in whose hands it will have a value proportioned to its weight of pure metal. The actual law, then, is that a cheaper money tends to drive a dearer money out of circulation; that it actually does so drive it when it so lowers the general purchasing power of money that the dearer is no longer worth as money what it is worth as bullion; and further, that if the metal of which the dearer money is composed is rising in value, the cheaper money may drive the dearer out, not by causing a rise in the general level of prices, but by preventing such a fall as would correspond with the rise in the metal of which the dearer money is composed.

Now, whether this expulsion of a dearer money by a cheaper is an expulsion of good money by bad depends upon circumstances. The best money for one of the most important of monetary functions — namely, that of serving as a standard for deferred payments — is the money of stablest value. If a "good money" is one that remains stationary in value, a relatively "bad money" is one that either falls below or rises above the standard set by such good money; while if of two moneys neither one is stationary, neither is entirely good; but that which is the nearer to an ideal unchanging standard is, other things being equal, the better of the two.

It follows therefore that, while bad money may drive good money out of circulation, good money may also drive out bad, or one money which is more or less bad may drive out another of a like defective character. That which remains in circulation when another is expelled, is always the one of smaller unit value. If it has become smaller by falling below a just standard, to which the other remained true, the case is one in which bad money drives out good; if it has come to be the smaller by remaining true while the other rose, the case is one in which good money drives out bad; and, finally, if it has come to be the smaller by falling below a just standard, while the other rose above it, the case is one in which one bad money drives out another.

To the cases already considered two others may be added; for, relatively to a standard existing at a given time, it is conceivable that two kinds of money may both either fall or rise in value, but in unequal degrees. If they fall, the one that falls least is the one that under Gresham's law is liable to be driven out of circulation; and this is a case in which a better money is expelled by a worse, since the one that falls least is, under the supposed conditions, the one that varies least from the standard. If they rise, the one that rises most is the one that is liable to be expelled, and as this is also the one that varies most from the standard, the case is one in which a worse money is expelled by a better.

In the case already noticed, where one money falls below and another rises above the value conceived of as a standard, there may be room for argument as to which is the better and which the worse, unless one varies from the standard materially more than the other. If they are equal in this respect, they may be considered equally faulty, if viewed solely with reference to their fitness for use as a standard for deferred payments; but their comparative merit as regards the other functions of money, especially that of serving as a medium of exchange, may be a debatable question. Much would of course depend on their comparative portability, divisibility, and general physical adaptation to the special requirements of the given case; but, aside from this point, conflicting

views are held as to the comparative merits and demerits of appreciating and depreciating currencies respectively, when viewed as media of exchange. There are those who maintain that, with a view to this function, a slight progressive depreciation is positively preferable to perfect stability, as tending, through the stimulating influence of rising prices, to beget a spirit of enterprise and promote industrial activity. Leaving these to settle the question as they may with those who believe that the stimulating influence of rising prices is closely analogous to that of alcoholic liquors on the physical man, and that the enterprise and activity so engendered are mainly in the direction of unhealthy and pernicious speculation, I am content to let it be considered an open question whether in the case here in view the worse money expels the better or the better expels the worse, or whether that which is expelled, and that which expels it, are about equally faulty.

My own opinion is that the situation just discussed is quite different from that which would arise in this country if the advocates of unconditional free silver coinage should gain control of the government. The assumption in the case just considered was that the depreciation of one kind of money was equalled by the appreciation of the other; or, in other words, that their deviation from a just standard — the one downwards, and the other upwards — was about equal. The time allotted to this paper does not permit any detailed examination of facts as to the comparative degrees in which the changed value relations between silver and gold are due to the depreciation of the former on the one hand, or to the appreciation of the latter on the other. But if we could authentically determine for present purposes the level of values on which silver and gold both stood when the commercial ratio between them was about fifteen and a half to one, the deviation of silver from that level would, I have little doubt, be found to be much greater than that of gold. The great fall in the prices of wheat and certain other articles is interpreted by some as supporting a different conclusion; but such articles are exceptional, and in respect to some of them the influence of other causes than the currency is very conspicuous. If, then, we consider the two metals with reference to their comparative fitness to serve as standards for deferred payments, I deem it safe to say that the expulsion of gold by silver under the operation of free silver coinage, adopted without international co-operation, should such a thing occur, would be the expulsion of a better money by a worse. Gold may be in some measure a "bad money," as being on account of its appreciation, a more or less unjust standard for deferred payments; but silver, on account of its depreciation, would probably be far more unjust in the opposite direction.

The great difficulty is to agree upon a criterion by which the degree of each metal's departure from the old level of value can be determined. There is time here only for the remark that the general level of prices, or the relation of gold to goods, is a criterion which errs on the side of making the appreciation of gold seem greater than it is; while the relation of gold to labor, or, more broadly speaking, to industrial effort, errs, and perhaps just as widely, in the opposite direction. Viewing the value of a thing as a measure of the estimation in which it is held by the complex social being composed of the aggregate of competing individuals, it is possible to conceive a state of public feeling in which the general level of prices would be a just criterion of value. So, also,

it is possible to conceive of one in which the relation of money to industrial effort would be the true criterion.[1] But where these two criteria differ as the result of a changing relation between effort and goods, the chances are many to one that the actual feelings of men with regard to goods on the one hand, and effort on the other, will be such as to place the just criterion of value between the two.

RATE OF INTEREST IN THE UNITED STATES CONSIDERED GEOGRAPHICALLY. By HENRY FARQUHAR, U. S. Coast Survey, Washington, D. C.

[ABSTRACT.]

"EXTRA BULLETIN" No. 71, one of the latest publications of the Eleventh Census, is devoted to real-estate mortgages, their total amount, rate of interest, etc., in the different States and territories. Table No. 9 gives a summary, and it is to the column of this table which shows the average interest rate on these mortgages that attention is asked. The highest rate (10.90 per cent) is just double the lowest. Dividing them into six classes, designated V to X according to their integral figure, and indicating them upon a map of the country by six different sorts of shading, it is seen that all States of Class V are concentrated in a compact mass from New Hampshire to District of Columbia in the north-eastern part, that those forming Class VI are grouped close to V (Maine, and an area extending from Virginia and Tennessee to Wisconsin), while X contains only a few territories and new States in the mountain region bordered generally by IX, in one or two cases by VIII. The low rates belong generally to the more densely, the high to the more sparsely settled territory.

The correspondence between these figures and those indicating the silver sentiment, as indicated in the first test vote on the question in the 52d House of Representatives (on a motion made 24th March, 1892, to lay on the table a bill to resume free coinage of silver at the old ratio of 15.99 to 1, the advocates of the bill being all recorded as "noes"), is shown in the accompanying table, where the first column shows the serial order of the States in the second, the third the mean interest rate from the Census table, and the last two the ayes and noes on the question named. There is an obvious increase of noes and decrease of ayes with increasing rates, and an inspection of the sums for each class will show that (having regard to proportions) this movement is continuous. Table II exhibits this continuity in a remarkable manner, each increment in the interest rate, as we pass from group to group, showing a larger percentage of "noes" than the last. A part of this regularity, however, may be ascribed to accidents of the grouping; if the forty-eight States and territories be taken in the same number of groups of eight each, the numbers (in the first column of Table III) being those of Table I, we see that the movement is by no means so equable, though even this table shows an evident progression, — the accidental breaks being only more distinctly brought out.

[1] This subject was more fully treated in a paper on "Tests of Stability in the Value of Money," of which an abstract appears on a previous page. — E. T. P.

TABLE I.

MEAN INTEREST RATES ON MORTGAGES ARRANGED IN INCREASING ORDER WITH THE DISTRIBUTION OF VOTES ON A SILVER QUESTION.

CLASS V.

No.	State or Territory.	Rate.	Ayes.	Noes.
1	Massachusetts	5.44	11	0
2	New York	.49	28	1
3	Pennsylvania	.61	26	1
4	Connecticut	.64	4	0
5	Delaware	.71	1	0
6	Rhode Island	.72	2	0
7	New Jersey	.73	6	1
8	Maryland	.86	4	0
9	District of Columbia	.93	0	0
10	Vermont	.97	2	0
11	New Hampshire	.98	2	0
	Sum		86	3

CLASS VI.

12	Tennessee	6.00	1	7
13	Virginia	.02	0	8
14	West Virginia	.06	1	3
15	Maine	.15	4	0
16	Kentucky	.25	1	9
17	Ohio	.56	8	10
18	Illinois	.70	8	7
19	Indiana	.84	2	9
20	Wisconsin	.84	8	1
	Sum		33	54

CLASS VII.

21	Michigan	7.13	7	4
22	Iowa	.63	9	2
23	Minnesota	.66	3	2
24	Louisiana	.67	2	3
25	Missouri	.68	1	12
26	North Carolina	.72	0	8
27	Alabama	.98	0	6
	Sum		22	37

CLASS VIII.

28	Georgia	8.09	0	10
29	New Mexico	.19	0	0
30	Nebraska	.30	0	3
31	South Carolina	.37	1	3
32	Colorado	.57	0	1
33	Kansas	.68	0	6
34	California	.81	4	2
35	Washington	.84	1	0
	Sum		6	25

CLASS IX.

36	Arkansas	9.06	0	4
37	North Dakota	.35	1	0
38	Oregon	.45	0	1
39	South Dakota	.46	0	2
40	Nevada	.48	0	1
41	Mississippi	.50	0	5
42	Texas	.60	0	11
43	Utah	.70	0	0
44	Florida	.78	0	2
	Sum		1	26

CLASS X.

45	Wyoming	10.22	0	1
46	Idaho	.60	0	1
47	Montana	.61	0	1
48	Arizona	.90	0	0
	Sum		0	3
	Sum total		148	148

TABLE II.

COMPARISON OF SILVER SENTIMENT.

Class.	Ayes.	Noes.	Percentage Noes.
V.	86	3	3
VI.	33	54	62
VII.	22	37	63
VIII.	6	25	81
IX.	1	26	96
X.	0	3	100

TABLE III.

COMPARISON OF SILVER SENTIMENT; ANOTHER GROUPING.

Nos.	Ayes.	Noes.	Percentage Noes.
1–8	82	8	4
9–16	11	27	71
17–24	47	38	45
25–32	2	43	96
33–40	6	16	73
41–48	0	21	100

Accepting the conclusion, then, that the connection between these two orders of phenomena, high interest and strong silver sentiment, is causal and not merely accidental, how shall we explain it? High interest accompanies vigorous enterprise, and it might be claimed that the Silver States were thus shown to be the enterprising ones. Ascribing the high rates to oppression by "the creditor class," the movement for free silver might be looked upon as a natural protest against this tyranny by those who suffer from it. But the most probable explanation, in the author's view, is that which associates high interest inseparably with low credit, and regards the "silver craze" as merely one of the natural manifestations of that undeveloped state of public sentiment upon finance which is more than anything else the cause of low credit.

COXEY'S ARMY AND THE RUSSIAN THISTLE. By Prof. L. H. BAILEY, Cornell University, Ithaca, N. Y.

[ABSTRACT.]

THE so-called Russian Thistle (*Salsola kali*, var. *tragus*) has been introduced into the northwestern prairie States, and it has spread rapidly, and now threatens the agricultural prosperity of a vast area. The people are naturally much aroused, and amongst other measures a section has been inserted in the Congressional bill making appropriations to the Department of Agriculture, asking for $1,000,000 to be expended in the eradication of the pest. This demand has found additional support from the great numbers of unemployed men in the West, and it has been advertised as a means of supplying the Commonwealers with work. It is true, however, that the best means of keeping the weed in check is rotation of crops and good cultivation. When lands are well occupied by a vigorous crop, weeds are not troublesome. This is true of all weeds. In other words, proper and systematic farming is the best exterminator of weeds. If, then, the government undertakes to eradicate weeds, it must go directly into farming: it must take under its charge the agricultural economy of the infested region, it must overturn the present pernicious continuous cropping with wheat, and it must control and cultivate all waste lands. This is communism. Does not the proper office of government end when it has distributed information as to the best means of combating the weed, permitting the individual his freedom in his own farming?

THE FRANCHISE QUESTION. By Hon. STILLMAN F. KNEELAND, Brooklyn, N. Y.

[ABSTRACT.]

(*a*) *The present limitation of the Right of Franchise.*

1. *Infants, Idiots, and Insane Persons.*
   Reason: Want of capacity to cast an intelligent vote.
2. *Aliens.*
   1. Same reason in part.
   2. They should claim allegiance to the Government before they control its action.
3. *The "Superior Sex."*
   No reason except Man's will.

(*b*) *Further proposed Limitations.*

1. *All persons who cannot cast an intelligent vote.*

The reason which founded the rule in some cases should extend it to all cases of a like character.

2. *No person should cast a ballot that he cannot read.*

Reason: Such ballot is not intelligent, nor personal, nor safe. It is voting on information and belief. It is the informant's vote cast by a third person which practically leads to plurality voting. Same rule that prohibits hearsay evidence should prohibit hearsay voting.

3. *No person should be naturalized, who has not read either in his own or the English language the Declaration of Independence and the Constitution of the United States.*

While it may not be safe to disfranchise existing voters, we should lay stringent rules as to those who may claim the privilege hereafter. Nine-tenths of those naturalized at the present time have no comprehension of the Constitution they swear to protect.

(*c*) *The true line of demarcation:* — It runs not with race, nor with color, nor sex, but with capacity and character. Every ballot cast should not only be conscientious but conscious.

(*d*) *Compulsory voting:* — In local elections there is usually a falling off of at least 20 per cent of the total vote.

The politicians, the place-hunters, the corrupt, and the vicious always vote. They are interested. The stay-at-homes are the persons known as "Our best citizens."

Consequence: — Mayors who disgrace civilization; aldermen that either are or should be indicted; bankrupt treasuries and ruinous taxation.

Moral: — A man that can vote, and don't vote, should be made to vote.

We compel children to exercise school privileges. Why not compel parents to exercise franchise privileges, especially when equipped therefor at public expense?

Finally, when intelligence becomes the only standard, and when those within the limit are compelled to vote, then of necessity and with perfect safety the bars may be let down and the ladies at last rank among "Our best citizens."

SOME OBSERVATIONS ON THE SUBJECT OF TAXATION. By Hon. STILLMAN F. KNEELAND, Brooklyn, N. Y.

[ABSTRACT.]

THE question to be considered is not whether land, either with or without the improvements thereon, should be the only basis of taxation, but whether communities should be permitted to follow their own desires in collecting local taxes. In other words, shall there be home rule as to local taxation?

This question was submitted to the last legislature in New York State, and only failed of passage by seven votes. The large cities strongly supported the bill, and the agricultural communities were against it. The arguments in favor of the proposition were: —

(*a*) Land furnishes a perfect standard of value, is readily ascertained, absolutely un-hide-able, not changeable in seasons, never out of fashion, sometimes shop-worn, but never stolen or destroyed by fire; *whereas*,

(*b*) Personal property is perishable, transportable, stealable, and liable, on slight provocation and before the assessors come around, to vanish into thin air.

(*c*) Land being created by the Almighty, belongs to Him, subject to the right of usage in individuals, therefore subject to ground rent payable to His agent, the tax gatherer.

(*d*) Personal property being man-made, the absolute ownership is in individuals, and not primarily liable to rent in favor of any one except the individual creator or his assigns.

(*e*) The actual value of personal property per capita exceeds that of real estate, nevertheless, in the city of Brooklyn, in 1871, the assessed value of real estate was in round numbers $180,000,000, and of personal property $18,000,000. After the expiration of ten years we find that the assessed value of real estate increased nearly $300,000,000, and of personal property decreased $3,000,000, showing the increased refinement of perjury, or elasticity of conscience, the utter unreliability of personal property as a basis of taxation, and how slight the burden on real estate would be increased by the abolishment of personal property in levying taxes.

(*f*) Under the present law, women who invariably decline to swear off their personal assessments, and the wards of inherited estates who cannot do so, bear the burdens of personal taxation, while man, who hath an easy conscience and does all the voting, escapes. A very forcible example of taxation without representation.

The main argument against the proposition was, "The farmers are agin it, and the country fellers that voted for it last year got left."

This paper is only submitted for the purpose of calling attention to this subject, and to suggest the advisability of a fair test in separate localities. The principle of local option had the support of leading bankers and business men in this State, and is worthy of our serious consideration.

THE SCIENCE OF SOCIETY: — HAS THE TIME ARRIVED FOR THE FORMATION OF A COMPLETE AND FULLY ORGANIZED SECTION OF SOCIOLOGY BY THE ASSOCIATION. By JAMES A. SKILTON, 115 Broadway, New York City.

[ABSTRACT.]

THE topic to be treated from the point of view of the struggle for existence and survival, and of a Malthusian or other law of population applied to nations and civilization as well as to men.

The sciences of physic, chemistry, mechanics and engineering, geology, geography, zoölogy, and botany to be drawn upon or considered in the treatment of the topic.

In his recent book, "Social Evolution," Benjamin Kidd says, "There is, it must be confessed, no science of society properly so called."

Will the scientific world accept and adopt that confession?

In May, 1894, Mr. Spencer wrote: "In the United States, as here and elsewhere, the movement towards dissolution of existing social forms and reorganization on a socialistic basis I believe to be irresistible. We have had times before us and you have still more dreadful times before you — civil war, immense bloodshed, and eventually military despotism of the severest type."

What scientific basis can be found for this statement, if understood to declare the doom of modern civilization? And what, if any, are the means by which that doom may be averted?

A brief examination of these two statements in the light of the principles developed in the discussion of the foregoing points.

And, following, a presentation and discussion, or brief study, of the history of the United States, and particularly of the South and the North in contrast as bearing upon survival.

Followed by a comparison of modern civilization with the Asiatic civilizations and nations, particularly of China, and by a consideration of the forces that are now at work and have forced upon us and this age the necessity of dealing crucially with the active and decisive social problems of our time.

HAS GOLD APPRECIATED OR DEPRECIATED? By HENRY FARQUHAR, U. S. Coast Survey, Washington, D. C.

A NEW PLAN FOR PROPORTIONAL REPRESENTATION IN LEGISLATIVE BODIES. By Prof. WM. H. GOODYEAR, 222 E. 69th Street, New York City.

[To be printed in the New York Record and Guide.]

THE BRITISH LAND DIFFICULTY; POULTRY AND EGGS. By JAMES V. R. SWANN, 85 Percy Road, Shepards Bush, London, W., England.

WEEDS AS RELATED TO CIVILIZATION. By Dr. BYRON D. HALSTED, New Brunswick, N. J.

[ABSTRACT.]

AN account of the distribution of weeds in the progress of civilization.

THE PROVIDENTIAL FUNCTIONS OF GOVERNMENT. By B. E. FERNOW, U. S. Department of Agriculture, Washington, D. C.

ON SUICIDE: AN APPEAL, WITH REASONS WHY ALL AMERICAN LEGISLATION ON SUICIDE OUGHT TO BE REPEALED, AS ILLOGICAL IN PRINCIPLE, VICIOUS IN OPERATION, AND BARREN IN GOOD RESULTS. By W. LANE O'NEILE, LL. D., Downing Building, New York City.

EXECUTIVE PROCEEDINGS.

REPORT OF THE GENERAL SECRETARY.

THE forty-third meeting of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE was called to order on Thursday, August 16, 1894, at 10.30 A. M., in the large hall of the Polytechnic Institute, Brooklyn, New York, by the retiring President, Professor WILLIAM HARKNESS, of Washington, speaking as follows: —

Last year our meeting was contemporaneous with the grandest exposition the world has ever seen, and it was not surprising that many of our members preferred to spend their brief vacations there, rather than with us at Madison. But now the Columbian Exposition is only a memory, while the American Association for the Advancement of Science is again meeting with renewed vigor, and every prospect of a large and successful gathering. We represent all branches of science, and our presiding officer is taken from each in turn. Six years ago he was a well known anthropologist; after that we had a physicist, a botanist, a chemist, a geologist, an astronomer; and now we have again returned to that science whose field is the study of mankind, and have chosen for our President the illustrious anthropologist, Dr. DANIEL G. BRINTON, whom I have the pleasure of introducing to you.

President BRINTON assumed the chair with a few appropriate remarks.

The Rev. W. H. INGERSOLL then made the invocation.

Professor GEORGE W. PLYMPTON, Local Secretary, read the following letter from the absent Mayor of the city: —

Maplewood Hotel, White Mountains,
Maplewood, N. H., August 13, 1894.

PROFESSOR GEORGE W. PLYMPTON, SECRETARY,
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

DEAR SIR, — It is with great regret that I advise you that I shall be unable to be present at your meetings next week.

I had hoped to welcome your members to our city, and derive much information from the proceedings of your honorable body, but I am unavoidably detained, and therefore deprived of this pleasure.

I have always taken a deep interest in many of the questions which will be discussed at your meetings. In this progressive age, the pursuance of scientific studies has most wonderfully increased; it seems to lead the way, and opens the channels for advanced thought; it broadens the mind and cultivates

practical ideas so valuable to our every-day life. Brooklyn will be greatly benefited by these meetings and your coming among us; it will stimulate the love for the study of science, and I shall be greatly interested to hear of the success of your meetings.

Very truly yours,

CHARLES A. SCHIEREN.

On behalf of the Local Committee, Dr. TRUMAN A. BACKUS made the following address of welcome: —

Mr. President, Ladies and Gentlemen of the American Association for the Advancement of Science:

The Mayor of Brooklyn, our leader in all matters of municipal concern, has been generously and actively interested in promoting arrangements for the suitable reception of your learned Association. He fully appreciates the fact that our presence here is a notable incident in the history of our city. It was his purpose and our unanimous wish that he, at this hour and in this place, should address to you the words of official welcome to the city over which he presides. He regrets not more than we that he is imperatively denied the privilege of thus contributing to your pleasure. Your welcome, seemingly incomplete because of his absence, is none the less heartily given by our people.

Like all intelligent and patriotic Americans, the citizens of Brooklyn have for many weeks concentrated their anxious thoughts upon the outcome of the protracted strife in the halls of national legislation. To-day, at the opening of this session of your Association, dismissing our anxieties and summoning our sympathies, we are ready to give alert attention to the wisdom of your deliberations. More than words will tell, our people have been interested in the fact that you are lured from your laboratories and lecture-rooms, and that the day of our expectation has come. We know that the immeasurable power of your Association has been the chief source of that impulse to progress which, during recent decades, has brought blessing even to the unthinking, has given enlightenment to the preacher and inspiration to the teacher, and we know that the personal researches of individual members of your Association — some of them now numbered among the illustrious dead, some of them present here and now giving us exalted illustration of the possible achievement of the human mind — have begun the unveiling of the everlasting truth.

As you walk about our city you may notice Columbia Heights, Cambridge Place, Oxford Street. The villagers of early Brooklyn revered learning. It was their hope that this city should be the seat of a great university. You will not see the university, — we have none. Indeed, some of our modest citizens felt that, having no renowned school of learning, we could not give suitable reception to your learned order; but if you will stay with us long enough to ascertain the spirit of our people, you will honor their practical work in the dissemination of knowledge. While we have neither university nor endowed college, we have something better; we have a people who, without the appropriation of a dollar from State or municipal treasury, have developed and are maintaining three great private schools of high grade, with more than twenty-five hundred students, with well organized faculties, with courses of study higher than the course of study in the high school of any other American

city. No one of these institutions is a stock corporation; each one of them, generously supported by the public, appropriates its entire annual surplus revenue to the strengthening of its Faculty and its equipment. This Polytechnic Institute where we are met is one of several significant expressions of the spirit of our people towards education. The faith of its Trustees in the people of Brooklyn, and the works of its Faculty for the public good, — these forces, not the gift of the philanthropist nor the money of the State, created this great school and secured its thorough equipment. The same public spirit brought forth the Adelphi Academy; the same public spirit maintains the fame of Mrs. Packer's queenly gift; and all of this private high school training is demanded and liberally supported by a people whose annual appropriation for its public school system is about $2,500,000. And to crown the public school system, Brooklyn generously supports the largest free high school in the land.

He would be an ingrate indeed who should speak of the educational work of Brooklyn and leave unmentioned the bounteous gift of our chief philanthropist, Mr. Pratt. Applauded by the community in which he lived, he erected his spacious buildings, gave them lavish equipment, and even gave his life in organizing the most practical, the most extensive, the most advanced system of industrial instruction to be found in our country.

And perhaps the most significant expression of the interest of our people in the spread of knowledge is the work done by the unique organization of the Brooklyn Institute, with its twenty-six departments of research, its many courses of lectures, numbering eight hundred and fifty lectures during the last year's session, and with its more than three thousand subscribers.

Ladies and Gentlemen of this learned Association, our city, stirred by the spirit of inquiry, reverent towards learning, and ready to receive the gifts you bring, hails your coming and bids you welcome. May you give illustrations of the power and dignity and glory of high learning, such as shall uplift our people and impel our men of wealth to begin the building of a fitting superstructure upon the broad and strong foundation already laid.

In reply to the address of welcome, President BRINTON responded as follows: —

I feel it a peculiar privilege to reply, on behalf of the American Association for the Advancement of Science, to the hospitable words of welcome to which we have just listened.

We return you our thanks for the cordial reception which you have extended to our organization. We recognize and appreciate the advantages of a reunion in this populous and magnificent city, whose streets are lined with edifices erected by the munificence of a few for the benefit of the many, and which in so many features testifies to the broad liberality and the enlightened intelligence of its foremost citizens.

Like the birds and the fishes and the primitive tribes which it studies, the habits of our Association are migratory. It journeys from State to State and from city to city, gratefully recognizing the hospitality which is so liberally tendered it in all parts of our land. It presents itself as a guest of the nation, because in itself it represents the nation. Enrolling its membership with abso-

lute equality from all sections of our common country, it claims as its home and its rightful place of abode whatever roof it is invited to meet under, wherever the hospitality and the goodwill of citizens open to it their doors.

Nor does it come with empty hands. It is prepared to bestow as well as to receive. Like the native red man who once paddled his canoe on yon fair water where now floats the merchant navy of the world, for the gifts which it gladly accepts it feels it a duty to return other kinds of not less value.

The facilities you so generously place at our disposal, these spacious halls for our assembling, the attractive vista of public and private hospitality, the freedom of this noble city and the kindly expressions with which these have been tendered, these merit and meet in us keen appreciation and warm recognition. We thank you for them. They prove to us the friendly sympathy which man everywhere meets when he is engaged in the pursuit of the highest aim of which his nature is capable, — the disinterested search for truth.

You recognize in our national association that glorious purpose; and we come among you not as strangers, but as members of the same household, guided by the same motives which have prompted your enlightened citizens to erect this and other stately structures, and to dedicate them to the cause of knowledge, of learning, and of science.

It is the highest mission and the chief end of our Association to foster and stimulate this spirit wherever we go. Our hope is in every city where we meet to leave some permanent impress which will mark our sojourn there, to sow the seeds of the love of scientific work, and the devotion to positive knowledge. With this object in view we aim to frame the rules of our Association so flexibly that all with any interest in our pursuits may join us. The doors of our halls are thrown wide open, and every passer-by is invited to enter and share the enthusiasm which has moved us to this pilgrimage.

We are the representatives of the great republic of learning. No barrier is erected in the way of him or of her who would unite with us in membership. There is no restriction of caste or of color, of nationality or of sex. No naturalization is required to be admitted to the rights of our citizenship, no examination is demanded to gain entrance to our ranks. We well know that the cause of learning is as much benefited by the sympathetic assistance of those who have not the time or the opportunity to make it a special study, as by the industry of practical workers. The one supplements the other.

For that reason we welcome with peculiar warmth the intelligent public of the cities where we meet; we desire to see it fill our section meetings, either as auditors or members, and we count upon the influence thus exerted as one of the returns we can make for hospitality extended, and one of the benefits which our Association confers upon the country at large.

We begin to-day the forty-third annual meeting of our organization. For nigh half a century it has sought to collect together once a year the active workers in all the leading branches of scientific investigation, that they might learn to know each other as individuals, that differences of opinion might be the more readily harmonized, that the good work might be pushed forward by united effort, and that from all quarters of our vast country students could look to our central organization as one in which all are at home with equal rights and privileges. Beginning at first with but a small assemblage representing a

few branches of study, it now numbers over two thousand adherents and embraces all the prominent lines of research. Its forty-two volumes of transactions constitute an abstract and epitome of the scientific work of the United States for that many years. They embalm the names and the life results of many an honored associate now no longer with us, but whose activity is inwoven into the history of our land, and to whom its rapid development and present imposing rank are in no small measure due.

The influence of our Association is in the highest and best sense of the word *educational*. Its discussions are aimed to present the correct methods of scientific investigation, and to be guided by the true spirit of scientific inquiry. Permit me to expand this statement a little, for in it lies more than anywhere else the right to existence of our organization, and the best effects it can exert upon its own members or upon a community where it convenes.

The goal which we endeavor to obtain is *scientific truth;* the one test of which is, that it will bear untrammelled and unlimited investigation. Such truth must be not only verified, but always verifiable. It must welcome every test; it must recoil from no criticism, higher or lower, from no analysis and no scepticism. It challenges them all. It asks for no aid from faith; it appeals to no authority; it relies on the dictum of no master.

The evidence and the only evidence to which it appeals, or which it admits, is that which it is in the power of every one to judge, that which is furnished directly by the senses. It deals with the actual world about us, its objective realities and present activities, and does not relegate the inquirer to dusty precedents or the mouldy maxims of commentators. The only conditions that it enjoins are that the imperfections of the senses shall be corrected as far as possible, and that their observations shall be interpreted by the laws of logical induction.

Its aims are strictly beneficent. Its spirit is that of charity and human kindness. From its peaceful victories it returns laden with richer spoils than ever did warrior of old. Through its discoveries, the hungry are fed and the naked are clothed by an improved agriculture and an increased food-supply; the dark hours are deprived of their gloom through methods of ampler illumination; man is brought into friendly contact with man through means of rapid transportation; sickness is diminished and pain relieved by the conquests of chemistry and biology; the winter wind is shorn of its sharpness by the geologist's discovery of a mineral fuel; and so on, in a thousand ways, the comfort of our daily lives and the pleasurable employment of our faculties are increased by the administrations of science.

Scientific truth has likewise this trait of its own, — it is absolutely open to the world; it is as free as air, as visible as light. There is no such thing about it as an inner secret, a mysterious gnosis, shared by the favored few, the select illuminati, concealed from the vulgar horde, or masked to them under ambiguous terms. Wherever you find mystery, concealment, occultism, you may be sure that the spirit of science does not dwell, and what is more, that it would be an unwelcome intruder. Such pretentions belong to pseudo-science, to science falsely so-called, shutting itself out of the light because it is afraid of the light.

Again, that spirit of science which we cultivate and represent is at once modest in its own claims and liberal to the claims of others. The first lesson

which every sound student learns is to follow his facts and not to lead them. New facts teach him new conclusions. His opinions of to-day must be modified by the learning of to-morrow. He is at all times ready and willing to abandon a position when further investigation shows that it is probably incorrectly taken. He is in this the reverse of the opinionated man, the hobby-rider, and the dogmatist. The despair of a scientific assemblage is the member with a pet theory, with a fixed idea, which he is bound to obtrude and defend in the face of facts. Yet even toward him we are called upon to exercise our toleration and our charity; for the history of learning has repeatedly shown that from just such wayward enthusiasts solid knowledge has derived some of its richest contributions. So supreme after all is energy, that error itself, pursued with fervid devotion, yields a more bountiful harvest than truth languidly cultivated.

But perhaps the picture I have thus drawn of the spirit of scientific inquiry excites in the minds of some a certain antipathy, or at least a sense of dissatisfaction and incompleteness. To such, this description may sound narrow and materialistic; the results of scientific study thus rehearsed may appear vague, indefinite, incompetent to satisfy the loftier yearnings of the soul of man for something utterly true, immutably real.

Vain, indeed, were the life-work of our Association; bereft, indeed, were we of just claim upon your consideration, — did we appear before you with such a thankless and futile confession of the ultimate aim of our labor. But it is far, very far, otherwise.

All this prying into the objective, external aspect of things, this minute painstaking study of phenomena, this reiterated revision and rejection of results, are with the single aim of discovering those absolute laws of motion and life and mind which are ubiquitous and eternal, which bear unimpeachable witness to the unity and the simplicity of the plan of the Universe, and which reveal with sun-clear distinctness that unchangeable order which presides over all natural processes.

This is the mission of science, — noble, inspiring, consolatory, lifting the mind above the gross contacts of life, presenting aims which are at once practical, humanitarian, and spiritually elevating.

It is with the intention to train ourselves more and more in these directions that we assemble here to-day; and it is also with the hope and the confident belief that our presence among you with such purposes will lead you to unite with us and share our enthusiasms.

We feel the more justified in this belief from the courteous and sympathetic words with which you have welcomed us, and for which I again convey to you the earnest thanks of the Association.

Professor F. W. Putnam, the Permanent Secretary, then read the following list of names of deceased members, notices of whose death had been received since the last report: —

Gustave T. Beauregard, New Orleans, La. (30). Died Feb. 20, 1893, aged 75.

Edmund Burke Benjamin, New York, N. Y. (19). Born in East Bloomfield, N. Y., July 16, 1828. Died in New York, May 29, 1894.

Henry Bronson, New Haven, Conn. (41). Born in Waterbury, Conn., Jan. 30, 1804. Died in New Haven, Nov. 26, 1893.

GEORGE WILLIAM CURTIS, Staten Island, N. Y. (36). Born in Providence, R. I., Feb. 24, 1824. Died Aug. 31, 1892.

MARY E. GILBRETH, Brookline, Mass. (42). Born May 9, 1864. Died Aug. 8, 1894.

HERMANN A. HAGEN, Cambridge, Mass. (17). Born in Konigsberg, Prussia, May 30, 1817. Died in Cambridge, Nov. 9, 1893.

GEORGE H. HARRIS, Rochester, N. Y. (35). Born in West Greece, N. Y., Dec. 29, 1843. Died in Dansville, N. Y., Oct. 5, 1893.

NATHANIEL C. HUSTED, Tarrytown-on-Hudson, N. Y. (36). Died Nov. 19, 1891.

JOSIAH JACKSON, State College, Pa. (35). Died Oct. 10, 1893.

WILLIAM S. JONES, Cleveland, Ohio (37).

JAMES H. KELLOGG, Rochester, N. Y. (29). Died Dec. 6, 1891.

ELIAS LEWIS, JR., Brooklyn, N. Y. (23). Died Feb. 3, 1894.

WILLIAM LILLY, Mauch Chunk, Pa. (28). Born in Penn Yan, N. Y., June 3, 1821. Died in Mauch Chunk, Pa., Dec. 1, 1893.

SAMUEL LOCKWOOD, Freehold, N. J. (18). Born in Mansfield, Eng. Died Jan. 9, 1894, aged 75.

SPENCER C. MCCORKLE, Washington, D. C. (33).

MAITLAND L. MALLORY, Rochester, N. Y. (39). Died April 28, 1894.

ANDREW G. MILLS, Galveston, Texas (33). Died Feb. 2, 1894.

M. M. MITIVIER, Holyoke, Mass. (40). Died in July, 1892.

THOMAS MORONG, New York, N. Y. (35). Died 1894.

JOHN NEWTON, Pensacola, Fla. (7). Born near Pittsburgh, Pa., April 22, 1814. Died in Pensacola, Nov. 25, 1893.

MRS. WILLIAM R. PEDRICK, Lawrence, Mass. (33). Born Feb. 7, 1832. Died in Lawrence, Jan. 21, 1894.

EDMUND QUINCY, Boston, Mass. (11). Died Jan. 6, 1894.

ALICE M. S. SAWYERS, Fort Worth, Texas (34). Died April 25, 1893.

JOSEPH R. WALTON, Washington, D. C. (40). Died Sept. 23, 1892.

CYRUS M. WARREN, Brookline, Mass. (29). Died Aug. 13, 1891.

EDWIN FORBES WATERS, Boston, Mass. (29). Born in Petersham, Mass., in July, 1822. Died in San Francisco, Cal., April 18, 1894.

GEORGE H. WILLIAMS, Baltimore, Md. (33). Died in Utica, N. Y., July, 1894.

The PERMANENT SECRETARY read his report of the finances of the Association for the past year, including his cash account and the account of the invested funds.

The General Secretary, Professor H. L. FAIRCHILD, announced the election by the Council to membership in the Association, of 164 persons.

The GENERAL SECRETARY announced the nomination by the Council, to fill vacancy, of Dr. J. A. LINTNER, Albany, N. Y., as Vice-President of Section F. Dr. Lintner was unanimously elected Vice-President.

The following resolution, adopted by the Council, was read by the GENERAL SECRETARY: —

Whereas, There is evident need of carrying to the people through the public press a clearer and fuller knowledge of the work of the Association, therefore,

Resolved, That each Section be earnestly requested to appoint a special officer whose duty shall be the preparation for the newspapers of a plain and popular account of the proceedings of his Section.

Remarks explaining the intent of this resolution and the desirability of a new officer for each Section, to be known as the "Press Secretary," were made by the PRESIDENT.

The LOCAL SECRETARY announced certain details regarding railroad certificates and the Saturday excursions.

It was moved by the GENERAL SECRETARY, and voted, that daily sessions should be held on Thursday, Friday, Monday, Tuesday, and Wednesday, from 10 to 12 o'clock A. M., and from 2 to 5 o'clock P. M.

The session then adjourned.

EVENING SESSION OF THURSDAY, AUGUST 16. The Association convened in general session in the Academy of Music, President BRINTON in the chair.

A brief address of welcome in behalf of the city was made by the Hon. JACKSON WALLACE, Acting Mayor.

Professor WILLIAM HARKNESS delivered his address as retiring President [This address is printed in full in this volume.]

The PRESIDENT announced a reception tendered by the LADIES' RECEPTION COMMITTEE in the Art Association Hall, Montague Street, following adjournment.

The session then adjourned.

SESSION OF FRIDAY, AUGUST 17. The Association was called to order at 10.15 A. M., in the usual place, the PRESIDENT in the chair.

The GENERAL SECRETARY announced that a formal invitation had been received from the BUFFALO SOCIETY OF NATURAL SCIENCES, and from the BOARD OF ALDERMEN OF THE CITY OF BUFFALO, to hold the forty-fifth meeting of the Association, in 1896, in Buffalo.

Following are the invitations: —

Buffalo Society Natural Sciences,
Buffalo, N. Y., July 31, 1894.

PROFESSOR F. W. PUTNAM, SECRETARY
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

MY DEAR SIR:

I am instructed to notify you that at an informal meeting of this Society held on Monday evening, July 24, Hon. D. F. DAY presiding, it was unanimously voted to ask the American Association for the Advancement of Science to again honor Buffalo with its presence in August, 1896, as it has previously done in 1866, 1876, and 1886. I transmit herewith resolutions adopted by the Board of Aldermen of the Common Council of Buffalo. Will you kindly acknowledge receipt of my letter and oblige,

Very respectfully,
EBEN PEARSON DORR, JR., *Secretary.*

City and County Hall, Board of Aldermen,
Buffalo, Monday, July 30, 1894, at 2.30 o'clock, P. M.

Present — James Franklin, President of the Board, and Aldermen Boeckel, Bradish, Bullymore, Butler, Caldwell, Carey, Durr, Fechter, Kennedy, Kick, Kissinger, Maischoss, Menge, Robert, Scheu, Sheehan, Sullivan, Summers, Williams, Woltz, Zoeller — 22.

By Alderman ROBERT: —

Whereas, It has been the honor of the City of Buffalo to entertain that most distinguished body, the American Association for the Advancement of Science, on three different occasions of its Annual Conventions, in 1866, 1876, and 1886, and,

Whereas, The Buffalo Society of Natural Sciences has extended to the American Association for the Advancement of Science a unanimous invitation to again meet in this city, in August, 1896, be it therefore,

Resolved, That the Board of Aldermen of the City of Buffalo hereby approves of the said action of the Buffalo Society of Natural Sciences, and also extends on behalf of the City a most cordial request that the American Association for the Advancement of Science make for the fourth time within as many decades the Queen City of the Lakes the place of its annual deliberations, assuring the Association that Buffalonians, as in the past, will spare no pains to properly house and entertain its members.

Adopted.

The LOCAL SECRETARY made brief announcement of certain details concerning invitations and excursions.

To fill vacancies, the COUNCIL nominated EDGAR FRISBIE, Washington, D. C., for Vice-President of Section A, and C. E. BESSEY, Lincoln, Neb., as Vice-President of Section G. They were elected by formal ballot.

Adjourned.

EVENING SESSION OF FRIDAY, AUGUST 17. Held in the Art Association Hall, Montague Street, at 8 o'clock, President BRINTON in the chair.

The PRESIDENT introduced Mr. PAUL DU CHAILLU, who by invitation of the COUNCIL of the Association, delivered a lecture complimentary to the citizens of Brooklyn, entitled, "The Vikings, their Civilization and Expeditions."

SATURDAY, AUGUST 18. This day was given up to excursions, as follows:

One to Long Branch, complimentary to members and friends of the Association, presented by Mrs. ESTHER HERRMAN, who received the party, numbering about two hundred and fifty persons, at her residence at Long Branch, where she provided an elaborate collation, and gave to each guest a souvenir pin of unique and appropriate design, symbolical of her home by the sea and of the objects of the Association.

Another excursion to Cold Spring Harbor, Long Island, visiting the Biological Laboratory of the Brooklyn Institute, the station of the New York Fish Commission, and localities of interest to the geologists and botanists.

SESSION OF MONDAY, AUGUST 20. The Association was called to order at 10.15 A. M., in the usual place, the PRESIDENT in the chair.

The GENERAL SECRETARY announced a formal invitation from the educational and civic organizations of San Francisco to hold the forty-fourth meeting of the Association, in 1895, in that city. (See Proceedings of the Rochester Meeting, pp. 356, 357.) He then gave place to Professor JOSEPH LECONTE, of the University of California, as a representative of the inviting bodies, who addressed the Association, and presented the claims of the Pacific slope.

The PERMANENT SECRETARY announced the date and place of meeting of

the NOMINATING COMMITTEE, at the St. George Hotel, Monday evening, at 9.15 o'clock.

The GENERAL SECRETARY announced the following proposed amendment to the Constitution: —

The following words to be added to Article 3: "Any incorporated scientific society or institution, or any public or incorporated library, may be enrolled as a member of the Association by vote of the Council, by payment of the initiation fee; such, society, institution, or library may be represented by either the President, Curator, or Librarian presenting proper credentials at any meeting of the Association for which the assessment has been paid."

The LOCAL SECRETARY announced certain details concerning transportation and excursions.

The following resolution and notice was presented by Mr. J. A. SKILTON:

Whereas, We are witnesses of the fact that not only in America, but throughout what is known as modern civilization, grave social and economic problems are pressing for solution;

Whereas, Large numbers of men, organized and co-operating in various ways in different countries, are declaring the necessity of dissolving existing social forms and reorganizing society upon a different basis, and their set purpose to do so by force if necessary;

Whereas, In addition to many other signs of danger and warning known to all, Herbert Spencer has recently said: "In the United States as here and elsewhere the movement towards dissolution of existing social forms and reorganization on a socialistic basis I believe to be irresistible. We have bad times before us, and you have still more dreadful times before you, — civil war immense bloodshed, and eventually military despotism of the severest type;"

Whereas, The opinion is honestly held, not only among the ignorant, but among the cultivated, and also by many of the active and most intelligent writers and workers for the solution of these problems, that there "is no science of society properly so-called" according to which solutions may be safely urged and practically obtained;

Whereas, Not only in accordance with the stated objects of this Association, but under its expressed title, it is the function and duty of this Association to promote the advancement of all science, including the science of society: Therefore, be it

Resolved, That the time has come for this Association to take action on the side of progress according to scientific principles of law and order, and within its Constitution and objects, not for the purpose of resisting any propagandum, but for the purpose of enlightening and helping all desirable reforms, and the progress and survival of modern society, by the application of scientific principles and methods. And further, be it

Resolved, That the President of the Association be, and he hereby is authorized before the adjournment of this meeting to appoint a Committee of twenty-one Members and Fellows to be known as the Committee on Sociology, and to consist of two persons from each of the nine several sections from A to I, inclusive, with two members of the COUNCIL, and the PRESIDENT of the Association; the duty of which Committee shall be during the coming year to examine and fully consider the subject, and, if a majority of the Committee approve,

to formulate a plan for the organization of a new section to be known as Sociology, and to be as systematic and comprehensive as possible; and to report the same to the Association, together with a new article as a substitute for Article 22 of the Constitution, or an amendment thereof, accordingly, for consideration and action at the next annual meeting.

The undersigned hereby gives notice of the proposed amendment of Article 22 of the Constitution of the American Association for the Advancement of Science, at a General Session of the annual meeting of the Association held in Brooklyn, N. Y., Aug. 20, 1894, in accordance with Article 39 of the Constitution, entitled Alterations of the Constitution.

JAMES A. SKILTON.

The PRESIDENT said the resolutions would, under the rules, go to the COUNCIL.

EVENING SESSION OF MONDAY, AUGUST 20. Held in the Art Association Hall, President BRINTON in the chair.

An illustrated public lecture, complimentary to the citizens of Brooklyn and by invitation of the COUNCIL, was given by Prof. EDWARD D. COPE, entitled, "The Relation of Human Structure and Physiognomy to the other Mammalia."

SESSION OF TUESDAY, AUGUST, 21. The Association was called to order at 10.30 A. M., at the usual place, the PRESIDENT in the chair.

The PRESIDENT read the following letter from Dr. H. C. BOLTON.

Minnewaska, N. Y., August 20, 1894.

MY DEAR DR. BRINTON:

Some years ago the then PRESIDENT of the American Association for the Advancement of Science, was instructed by COUNCIL to express the wishes of the Association to the Royal Society in the matter of a *Subject-Index* to the Catalogue of Scientific Papers published in eight large volumes.

The Secretary of the Royal Society, Mr. M. FOSTER, has recently announced that "the Royal Society has determined to publish a Subject-Index and is already proceeding to put the matter in hand."

It seems to me that this important and welcome news should be announced to the Association by the PRESIDENT at a General Meeting, as it concerns every branch of science. The news will doubtless be hailed with delight by every Member and Fellow.

Yours sincerely,

H. CARRINGTON BOLTON,

Chairman Committee Indexing Chemical Literature.

The GENERAL SECRETARY announced the election of members of the Association making a total addition of new members to date of 213.

He also announced the election by the COUNCIL of the following Members as Fellows of the Association, August 21.

Baker, Prof. Arthur Latham, 28 Strathallan Park, Rochester, N. Y. (41). **A B**
Bartley, Elias H., M.D., 21 Lafayette Av., Brooklyn, N. Y. (33). **C**
Baskerville, Charles, University of North Carolina, Chapel Hill, N. C. (41). **C**
Bedell, Frederick, Ph.D., Cornell University, Ithaca, N. Y. (41). **B A**

Booth, Miss Mary A., Longmeadow, Mass. (34). F I G
Bristol, William H., Stevens Institute, Hoboken, N. J. (36). A B D
Carleton, M. A., Agric'l Exper. Station, Manhattan, Kan. (42). G
Charbonnier, Prof. L. H., University of Georgia, Athens, Ga. (26). A B D
Cheney, Lellen Sterling, 519 Lake St., Madison, Wis. (42). G
Christie, James, Pencoyd, Pa. (33). D
Christy, Samuel B., Univ. of Cal., Berkely, Cal. (35). D
Colburn, Richard T., Elizabeth, N. J. (31). I F H
Crandall, Prof. C. S , Fort Collins, Col. (40). G
Cresson, Dr. Hilborne T., 224 So. Broad St., Philadelphia, Pa. (39). H
Crockett, Charles W., Rensselaer Polytechnic Inst., Troy, N. Y. (29). A D
Daniel, John, Vanderbilt University, Nashville, Tenn. (38). B
Eccles, Robert G., M.D., 191 Dean St., Brooklyn, N. Y. (31). F C
Ford, Prof. D. R., Elmira, N. Y. (41). A B
Genung, Nelson H., Ardmore, Pa. (40). B
Gill, Adam Capen, Northampton, Mass. (38). E
Greene, Prof. Edward Lee, University of California, Berkeley, Cal. (42). G
Harrington, Prof. Mark W., Chief of Weather Bureau, Washington, D. C. (40). B
Hayes, Charles Willard, U. S. Geol. Survey, Washington, D. C. (41). E
Hazen, Henry Allen., P. O. Box 427, Washington, D. C. (33). B
Humphreys, William J., Washington College, Chestertown, Md. (42). B
Jones, Lewis R., Burlington, Vt. (41). G
Lamb, Daniel S., M.D., 800 10th St., N. W., Washington, D. C. (40). H
Lefavour, Prof. Henry, Williams College, Williamstown, Mass. (42).
Lennon, William H., Brockport, N. Y. (31). G C
MacMillan, Prof. Conway, Univ. of Minn., Minneapolis, Minn. (42). G
Marvin, Frank O., University of Kansas, Lawrence, Kan. (35). D
Metcalf, William, Pittsburg, Pa. (33). D
Miller, William S., M.D., 923 West Johnson St., Madison, Wis. (42). F
Moreland, Prof. S. T., Lexington, Va. (33). B D
Ross, Prof. Edward A., Cornell University, Ithaca, N. Y. (41). I
Rowlee, W. W., Cornell University, Ithaca, N. Y. (41). G
Russell, H. L., Ph.D., Poynette, Wis. (41). G
Sayre, Robert H., South Bethlehem, Pa. (28). D
Sheldon, Samuel, A.M., Ph.D., Polytechnic Institute, Brooklyn, N. Y. (42). B
Smith, James Perrin, Ph.D., Ass't Prof. of Paleontology, Leland Stanford Junior University, Palo Alto, Cal. (37). C E
Smyth, C. H., Jr., Clinton, N. Y. (38). E
Sudworth, George B., Dept. of Agric., Forestry Div., Washington, D. C. (41). G
Thomas, Prof. M. B., Crawfordsville, Ind. (41). G
Uline, Edwin Burton, Lake Forest, Ill. (42). G
Weld, L. G., State University of Iowa, Iowa City, Ia. (41). A
Williams, Prof. Edward H., Jr., Box 463, Bethlehem, Pa. (25). E D
Williams, Prof. Thomas A., Agric. College, Brookings, So. Dakota (42). G
Wolff, Dr. J. E., 15 Story St., Cambridge, Mass. (36). E
Wright, Carroll D., Dept. of Labor, Washington, D. C. (41). I

The GENERAL SECRETARY then read the following resolution, which had been approved by the COUNCIL and ordered to be read in General Session:

Resolved, That the Section of Anthropology of the American Association for the Advancement of Science desires to place upon record its deep appreciation of the service to its branch of investigation rendered by Prof. F. W. PUTNAM in the admirable installation of the collections in the Department of Ethnology of the World's Columbian Exposition at Chicago, in 1893, and its confident belief that the public display of objects there arranged under his judicious supervision will form a new era in the history of anthropologic science in America.

The following proposed amendments to the Constitution were announced by the GENERAL SECRETARY:—

To change Article 22 by omitting in the name of Section E the term "Geography," and by inserting in the list of Sections a new Section entitled "J — Geography."

To change Article 22 by substituting for the Section name, "I — Economic Science and Statistics," the following words: "I — Social and Economic Science."

Mr. W. H. HALE submitted the following proposed amendment: —

To amend Article 32 of the Constitution by adding to the first sentence of said Article the words, "and shall include all Fellows and Members of the Association who reside at such place."

The PERMANENT SECRETARY announced that the COUNCIL had voted from the research fund grants of money, as follows: —

For a Table at the Biological Laboratory at Woods Holl, $100.00.

To Messrs. E. W. Morley and W. A. Rogers, for experimental work upon Interferential Comparator, $100.00.

To Dr. Franz Boas, to complete Anthropometric Measurements of American Indians, $200.00.

The GENERAL SECRETARY presented the following nominations by the NOMINATING COMMITTEE for Officers of the Association for 1895: —

For PRESIDENT:

E. W. MORLEY, Cleveland, Ohio.

For VICE-PRESIDENTS:

A. Mathematics and Astronomy. — E. S. HOLDEN, Mt. Hamilton, Cal.
B. Physics. — W. LECONTE STEVENS, Troy, N. Y.
C. Chemistry. — WILLIAM MCMURTRIE, Brooklyn, N. Y.
D. Mechanical Science and Engineering. — WM. KENT, Passaic, N. J.
E. Geology and Geography. — JED. HOTCHKISS, Staunton, Va.
F. Zoology. — D. S. JORDAN, Palo Alto, Cal.
G. Botany. — J. C. ARTHUR, Lafayette, Ind.
H. Anthropology. — F. H. CUSHING, Washington, D. C.
I. Economic Science and Statistics. — B. E. FERNOW, Washington, D. C

For PERMANENT SECRETARY:

F. W. PUTNAM, Cambridge, Mass., for new term of five years.

For GENERAL SECRETARY:

JAMES LEWIS HOWE, Lexington, Va.

For SECRETARY OF THE COUNCIL:

CHARLES R. BARNES, Madison, Wis.

For SECRETARIES OF THE SECTIONS:

A. Mathematics and Astronomy. — E. H. MOORE, Chicago, Ill.
B. Physics. — E. MERRITT, Ithaca, N. Y.
C. Chemistry. — W. P. MASON, Troy, N. Y.
D. Mechanical Science and Engineering. — H. S. JACOBY, Ithaca, N. Y.
E. Geology and Geography. — J. PERRIN SMITH, Palo Alto, Cal.
F. Zoology. — S. A. FORBES, Champaign, Ill.
G. Botany. — B. T. GALLOWAY, Washington, D. C.
H. Anthropology. — ANITA NEWCOMBE MCGEE, Washington, D. C.
I. Economic Science and Statistics. — E. A. Ross, Palo Alto, Cal.

For TREASURER:

R. S. WOODWARD, New York, N. Y.

The GENERAL SECRETARY was unanimously authorized to cast the ballot of the Association for the persons nominated. The Chair declared them duly elected.

The LOCAL SECRETARY made announcements concerning the proposed excursion of the American Forestry Association to the White Mountains.

The PRESIDENT announced the following action by the NOMINATING COMMITTEE concerning the time and place of the next meeting: —

Resolved, That it is the sense of this Committee that the Association meet in San Francisco in 1895, provided that satisfactory railroad rates can be obtained, and that the matter of place and time be left in the hands of a Committee, said Committee to have power to act, and with permission to add to its number.

The Committee was constituted as follows: Professor Joseph LeConte, Dr. D. G. Brinton, Professor F. W. Putnam, Professor J. Perrin Smith, Hon. G. G. Hubbard, and Dr. J. L. Howe.

Announcements concerning excursions were made as follows: —

By Mr. B. E. FERNOW, describing the proposed excursion of the Forestry Association to the White Mountains.

By the PERMANENT SECRETARY, announcing free tickets to members to Glen Island.

By Professor F. W. HOOPER, stating that the special scientific excursions should be arranged separately by the Sections.

EVENING SESSION OF TUESDAY AUGUST 21. Held at the Art Association Hall at 8 o'clock, President BRINTON presiding.

A public lecture, illustrated by lantern views, complimentary to the citizens of Brooklyn, by invitation of the COUNCIL, was delivered by Professor B. E. FERNOW, of Washington, on "The Battle of the Forest."

Announcement was made by Mr. GEORGE H. MOSES, Secretary of the New Hampshire Forestry Commission, regarding the proposed excursion to the White Mountains, and by the PRESIDENT on a proposed geological excursion to Staten Island and the New Jersey Highlands, to be conducted by Mr. ARTHUR HOLLICK.

SESSION OF WEDNESDAY, AUGUST 22. Meeting held at the usual place at 11 A. M., the PRESIDENT in the chair.

Mr. GEORGE H. MOSES, Secretary of the New Hampshire Forestry Commission, announced the details concerning the proposed excursion to the White Mountains.

The GENERAL SECRETARY presented the following business:—

Notice of an amendment to the Constitution, as follows,—

To add to Article 15 the following words: "The Treasurer shall give bonds for the faithful performance of his duties in such manner and sum as the COUNCIL shall from time to time direct."

The following recommendation from the COUNCIL was adopted:—

That the sum of $100.00 be appropriated to Professor Franklin W. Hooper, in behalf of the Biological Laboratory at Cold Spring Harbor, to be devoted to defraying the expense of original research, the nature of this research to be subject to approval by a Committee selected by the COUNCIL.

The election of two new members was announced, making a total list of 216.

The following recommendation from the COUNCIL was presented:—

That in recognition of their pioneer work in American Science, the surviving Founders of the Association who have maintained an interest in scientific matters be elected to life membership.

The following named founders being known at this time:—

Charles E. West, Brooklyn, N. Y.; Epes S. Dixwell, Cambridge, Mass.; Thomas T. Bouvé, Boston, Mass.; James D. Dana, New Haven, Conn.; Traill Green, Easton, Pa.; J. H. Redfield, Philadelphia, Pa.; Bela Hubbard, Detroit, Mich.; James Hall, Albany, N. Y.

Mr. W. H. HALE moved the adoption of this recommendation, and remarks seconding the motion, with particular reference to Dr. Charles E. West, of Brooklyn, were made by W. LECONTE STEVENS and D. S. MARTIN.

The recommendation was unanimously adopted.

Adjourned.

EVENING SESSION OF WEDNESDAY, AUGUST 22. Held at the Art Association Hall at 8.30 o'clock, the PRESIDENT in the chair.

The GENERAL SECRETARY announced election to membership of Augustus Ruland, Brooklyn, N. Y., and Warren Higley, New York, N. Y., making a total of 218 names.

A proposed amendment to the Constitution, offered by D. S. MARTIN, was presented, to the effect that the name of Section E be changed to read "E—Section of Geology and Mineralogy."

The Reports of the Special Committees were taken up and acted upon as follows, in accordance with recommendations of the COUNCIL: —

Committee on the Maintenance of Timberlands and on the Development of the Natural Resources of the Country. — This Committee presented the following report: —

To the Council and Members of the American Association for the Advancement of Science: Your Committee on Forestry reports that the forestry movement is making progress but slowly. Since our last report the States of Maine, New Hampshire, New Jersey, and Pennsylvania have taken forward steps by the enactment of laws and establishment of forest commissions; while the States of California and Colorado have retrograded, abandoning, for political reasons, the policy inaugurated to advance forestry interests.

The general government of the United States, in pursuance of the policy established by the law of March 3, 1891, has made further reservations of public timberlands, so that the area of forest reservations embraces now nearly 18,000,000 acres. These reservations, however, are still left without appropriate administration or protection, so that the advantages of making them become nugatory, and in some cases are even turned into disadvantage.

Your Committee, therefore, recommends, in order to strengthen the hands of those who are active in securing a rational action of the United States Government in this direction, that the American Association for the Advancement of Science consider and pass the following resolutions: —

Resolved, That the American Association for the Advancement of Science hereby expresses its conviction that the necessity for a thorough system of protection of the public forests against destruction by fire, by the ravages of sheep, and by the injudicious use of the axe has become imperative, — such protection being demanded not only in the interest of our rapidly diminishing lumber resources, but for the conservation of equable water supply, and for the irrigation of reclaimable arid regions.

Resolved, That, while the policy of reserving public timberlands for forest purposes is a step in the right direction, it must fail to accomplish its object and lose its value unless a proper administration of the reserves is at the same time inaugurated, such administration providing not only for protection against depredations, but also for the rational use and reproduction of the timber on the same, and of all the resources contained in them. We urge, therefore, the passage of a law providing for such protection and control of the forest reserves, and the rational use of the timber and other resources therein, and we recommend the extension of this policy of reservation, protection, and rational use over the entire public timberlands, wherever practicable.

Resolved, Further, that this Association suggests the propriety of utilizing the military forces for the purpose of protecting the public forest property against depredations in the absence of properly established civil organization for the purpose; and that to train army officers for such duties as may be assigned to them in connection with the forest reserves, a Chair of Forestry be established at West Point.

Resolved, That these resolutions be transmitted to the President, the heads of Departments, and both Houses of Congress.

Your Committee does not ask for its continuance, but suggests that the sub-

ject with which it has been charged is of greatest importance in the economic development of the country, worthy to be constantly watched and furthered by this Association, and recommends that a new Committee for this purpose be appointed.

For the Committee,

B. E. FERNOW,
CHARLES E. BESSEY.

The report was adopted and the Committee discharged.

Committee on the Association Table at the Biological Laboratory at Woods Holl. — This Committee had made a report which was referred by the COUNCIL to Sections F and G. The report of the combined Sections was presented as follows: —

To the COUNCIL: The Sections of Zoölogy and Botany (F and G) request:

That the Association continue its subscription of $100.00 for an "Investigator's Table" at the Marine Biological Laboratory at Woods Holl, Mass.

The two Sections, in joint session, also make the following suggestions for the award and government of the table subscribed for by the Association:

1. That the table shall be known as the American Association for the Advancement of Science Table.

2. That the award of this table shall be entrusted to a Committee of five, consisting of the Vice-President and Secretary Elect of each Section (F and G), and of the Director of the Marine Biological Laboratory (at present C. O. Whitman).

3. Any Fellow or Member of the Association shall be eligible for appointment to the table. (An applicant for membership to the Association will be considered as a member, and therefore eligible.)

4. Applications for the table are to be made to the PERMANENT SECRETARY, who shall forward them to the senior VICE-PRESIDENT of Sections F and G, seniority being determined as in Section II. of the Constitution, — *i. e.*, according to continuous membership.

5. That the holders of the Association's table are expected to give proper credit for the use of the table in all published results of investigations carried on at the table.

Adopted by the Sections in joint session.

J. B. SMITH, *Secretary of Section F*,
C. R. BARNES, *Secretary of Section G*.

Upon recommendation of the COUNCIL the above report was adopted, the former Committee discharged and a new Committee named, as specified in the report.

Committee on Recording and Classifying Fossil Faunas and Floras. This Committee reported progress and requested continuance. Upon recommendation of the COUNCIL the Committee was continued.

Committee on Instruction in Botany in the Secondary Schools. This Committee had made a verbal report to the COUNCIL. Upon recommendation of the COUNCIL it was voted to continue the Committee.

Committee on Biological Nomenclature. This Committee presented no report, but on recommendation of the COUNCIL the Committee was continued.

Committee on Standards for Astronomical and Physical Units. This Committee presented no report, but upon recommendation of the COUNCIL the Committee was continued.

Committee on the endowment of Research Fund. This Committee having made a verbal report to the COUNCIL, was, by recommendation of the COUNCIL, continued.

Committee to Memorialize Congress for a National Park in the State of Washington. This Committee having made a verbal report to the COUNCIL, it was, upon recommendation of the COUNCIL, voted to continue the Committee.

Committee to apply to Congress for a Reduction of the Tariff on Scientific Books and Apparatus. This Committee made no report, and, on recommendation of the COUNCIL, it was discharged.

Committee to Memorialize Congress to take steps for the Preservation of Archæologic Monuments on the public lands. The Committee made a verbal report, and it was voted to continue the Committee.

Committee on Water Analysis. The Committee made a final report (printed in Section C of this volume). The report was accepted, and the Committee was discharged.

Report of Committee on Indexing Chemical Literature. The report was accepted (printed in Section C in this volume), and the Committee continued.

In response to a request of Section H, the COUNCIL recommended the appointment of a Committee on "Anthropological Instruction," to be constituted as follows: D. G. BRINTON, F. W. PUTNAM, FRANZ BOAS, FREDERICK STARR, A. W. BUTLER. Adopted.

Professor PUTNAM presented the following communication:

To the American Association for the Advancement of Science: The Committee to urge the preservation of the Earthworks at Anderson, Ind., which at its request was discharged last year, begs to state that the people of Anderson have considered the proposition to preserve the ancient earthworks at that place, and will probably include them in a public park for which arrangements are now being made.

A. W. BUTLER
F. W. PUTNAM } *Members of the ex-committee.*

Mr. MCGEE, for the Committee to confer with a Committee of the founders and friends of the journal *Science*, read a report as modified and adopted by the COUNCIL, with the recommendation that it be adopted by the Association.

Remarks upon the report were made by W. H. HALE, JAMES A. SKILTON, E. T. PETERS, W. A. ROGERS, and W J MCGEE.

The report was adopted without dissenting votes. [As the publication of the journal has been continued under other arrangements than those contemplated in the report the report is omitted. F. W. P.]

The PERMANENT SECRETARY read the following statistics of the meeting:—

There have been presented addresses and papers as follows: The President's address, 8 addresses by Vice-Presidents, 6 reports of Committees, 3 public lectures, 202 papers were entered, of which 178 have been read in Sections as follows: Section A, 12; Section B, 24; Section C, 15; Section D, 8; Section E, 26; Section F, 10; Section G, 22; Section H, 41; Section I, 19.

219 Members have been elected, of whom 4 are Life Members. 49 Members have been made Fellows.

490 Members and Associates have been registered from the following places: Brooklyn 64, New York State (not including Brooklyn) 155, Washington, D. C., 44, Massachusetts 86, New Jersey 27, Pennsylvania 19, Connecticut 17, Ohio 16, Michigan 12, Illinois 11, Iowa 10, Wisconsin 9, Indiana 8, Missouri 7, West Virginia 6, Virginia 6, New Hampshire 4, Maryland 4, Kansas 3, Georgia 3, Nebraska 3, California 3, Kentucky 2, South Carolina 2, Maine 2, Texas 2, Colorado 2, Vermont 2, North Carolina 1, Alabama 1, Minnesota 1, Canada 8.

The GENERAL SECRETARY read the following resolutions of thanks, and moved their adoption: —

Whereas, The Brooklyn meeting of this Association is one which will be long remembered with pleasure by all members who have been in attendance; and

Whereas, The success and pleasure have been largely due to the efforts of certain individuals, and the generous hospitality of certain institutions and persons: Therefore,

Resolved, That the sincere and hearty thanks of the Association be and are hereby tendered—

1. To the LOCAL COMMITTEE for its successful labors in providing facilities for the scientific work and the recreation of the Association.

2. To the TRUSTEES OF THE POLYTECHNIC INSTITUTE for the free use of the Institute Building by the Association.

3. To the TRUSTEES OF THE PACKER COLLEGIATE INSTITUTE for the free use of the Institute Building for the meetings of the Association.

4. To the BROOKLYN ART ASSOCIATION for the free use of its galleries for the reception tendered to the Association by the Local Committee, and for evening lectures and gatherings of the Association.

5. To Mrs. ESTHER HERRMAN, of New York City, for the excursion to Long Branch and return and entertainment at Long Branch, presented by her to members of the Association.

6. To the Hon. MARSHALL MCDONALD, United States Fish Commissioner, Woods Holl, Mass., for his services in placing at the disposal of the American Association during its session, for dredging purposes, the United States Steamer "Fish Hawk," and for the direction of excursions made during the meetings of the Association.

7. To the POSTMASTER OF BROOKLYN for services rendered in placing a branch post-office at the headquarters of the Association in the Polytechnic Institute.

8. To the WESTERN UNION TELEGRAPH COMPANY for establishing an office at the headquarters of the American Association, and for furnishing to members of the Association service at reduced rates.

9. To the NEW YORK AND NEW JERSEY TELEPHONE COMPANY for establishing a telephone office at the headquarters of the Association, for furnishing the free use of the telephone throughout the City of Brooklyn, and for reduced rates on long distance messages.

10. To the PRESS OF BROOKLYN AND NEW YORK for full and valuable reports of lectures, addresses, and proceedings of the meetings of the Association.

11. To the UNION FERRY COMPANY, of Brooklyn, for the free use of the

ferry-boat "Pierrepont" for an excursion to points of interest in New York harbor.

12. To Col. HENRY T. CHAPMAN, JR., for placing on the walls of the Art Building, for the benefit of the American Association during its reception and evening meetings, a valuable and interesting collection of paintings.

13. To the KNICKERBOCKER STEAMBOAT COMPANY for the use of boats for excursions to Cold Spring Harbor and West Point at reduced rates.

14. To the JOHN H. STARIN STEAMBOAT COMPANY for free tickets to Glen Island and return.

15. To the BROOKLYN HEIGHTS TROLLEY COMPANY for 2,000 car tickets for free distribution among the members.

The resolutions were seconded by addresses made by H. C. HOVEY, HENRY FARQUHAR, Mrs. NELLIE S. KEDZIE, W. A. ROGERS, F. W. PUTNAM, S. A. LATTIMORE, W J MCGEE, and the PRESIDENT.

The resolutions were unanimously adopted.

In response to the sentiments of the resolutions remarks were made by Prof. F. W. HOOPER, representing the Local Committee and the people of Brooklyn, and by the Hon. STILLMAN F. KNEELAND.

It was voted that the formal adjournment of the forty-third meeting of the Association should be on Saturday, August 25, 1894. The General Session then adjourned.

HERMAN LEROY FAIRCHILD,
General Secretary.

REPORT OF THE PERMANENT SECRETARY.

AT the Madison meeting in 1893, by vote of the Association, the President and Permanent Secretary were appointed a committee with power to determine upon the place for holding the next meeting. The City of Brooklyn was suggested by several members; and Dr. W. H. Hale made a strong appeal in behalf of that city, with the assurance that the Association would be cordially welcomed. In due time the following letters, inviting the Association to hold its meeting in Brooklyn, were received.

Polytechnic Institute, President's Room,
Brooklyn, N. Y., Oct. 30, 1893.

TO THE AMERICAN ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE.

At a meeting of the Faculty of the Polytechnic Institute of Brooklyn, held Oct. 30, 1893, it was resolved "that the Faculty, having been informed that the American Association for the Advancement of Science intend to hold their next annual meeting in this city, hereby instruct their Secretary to tender to the Association the use of the rooms of the Institute during their session."

Which the Secretary hereby attests,

Respectfully yours, RUFUS SHELDON,
Secretary, Fac. B. P. I.

The Packer Collegiate Institute,
Brooklyn, N. Y., Nov. 7, 1893.

PROF. F. W. PUTNAM,
SECRETARY OF THE AMERICAN ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE, SALEM, MASS.

DEAR SIR:

The Trustees and Faculty of the Packer Collegiate Institute have pleasure in hearing that your distinguished Association contemplates holding its next annual meeting in the city of Brooklyn. The officers of the Packer Institute will do whatever they may to promote your convenience in making arrangements for such meeting. Our school building, located near the City Hall, will be placed at your disposal, in case you find it suited to the needs of the Association.

Very respectfully yours,
JOSHUA M. VAN COTT,
President Board of Trustees,
TRUMAN J. BACKUS,
President of the Faculty.

The Brooklyn Institute of Arts and Sciences,
Brooklyn, April 17, 1894.

PROF. FREDERICK W. PUTNAM,
SECRETARY OF THE AMERICAN ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE,
PEABODY MUSEUM OF ARCHÆOLOGY,
HARVARD UNIVERSITY, CAMBRIDGE, MASS.

MY DEAR SIR:

On behalf of the Mayor, the citizens of Brooklyn, and the educational institutions of the city as represented in a General Meeting, held in the Common Council Chamber in the City Hall on Saturday morning, April 14th, I beg leave to extend, through you, to the American Association for the Advancement of Science a most cordial invitation to hold its next meeting in Brooklyn, in August next.

Very respectfully yours,
FRANKLIN W. HOOPER,
General Secretary.

The cordial reception given to the Association which was voiced in the several addresses of welcome, printed in the preceding report of the GENERAL SECRETARY, showed that those members who best knew the city were not mistaken in their estimate of its hospitality. The readiness of its citizens to encourage and advance science was self-evident from the existence of several active institutions and schools of science and art. Four of these, — the Polytechnic Institute, the Packer Collegiate Institute, the Art Association and the Long Island Historical Society, — furnished ample and admirable halls for the meetings and offices of the Association and affiliated societies. The officers of these institutions and of the Brooklyn Institute of Arts and Sciences took an active part in all the arrangements for the accommodation of the Association; and the officers of the

Brooklyn Institute regretted that their magnificent building, in process of construction, could not also have been at the service of the Association.

The preceding report of the GENERAL SECRETARY gives an account of the various important matters brought before the Association, as well as the usual statistics of the meeting and the notices of the several excursions and receptions so generously and cordially extended to the members of the Association. It is therefore only necessary for me to present the annual statistics of my office.

Of the 219 members elected since the Madison and during the Brooklyn meeting, 2 have declined membership, 1 became an associate member, 161 have perfected their membership (as has 1 elected at the Madison and 1 at the Rochester meeting); 11 members have paid their arrears and have been restored to the roll; 8 founders of the Association have been made honorary life members, 2 of these being restored to the list of members, — making 176 names added to the roll since the Madison volume was published.

From the Madison list 17 names have been transferred to the list of deceased members; 35 members and fellows have resigned, and 261 have been omitted for arrearages, — making a deduction of 313 from the list.

Four members have become life members; 41 members have been transferred to the roll of fellows, among them one whose name was restored under original date of fellowship by vote of Council.

The following is a comparative statement of the roll as printed in the Rochester and Madison volumes, and in the present volume: —

	Rochester.	Madison.	Brooklyn.
Living Patrons	3	2	2
Corresponding members	2	2	2
Members	1,246	1,138	1,042
Living Honorary Fellows	2	1	1
Fellows	784	796	755
	2,037	1,939	1,802
Honorary Life Members (Founders)			8

The distribution of publications since the last report is as follows: —

Memoirs No. 1: sold 1 copy, presented 2 copies. Transactions: sold 8 copies. Proceedings, Vols. 1–41: delivered to members, 82; sold, 95; exchanges, 2; duplicate copies to members, 2; presented, 39; bought 7 copies; received as donations, 4; returned from exchanges, 10.

Vol. 42: delivered to members, 1,354; sold, 20; exchanges, 242; presented, 2; returned from members, 3; bought, 2 copies. Vol. 43: bought, 1 copy.

The following cash account gives the receipts and expenditures for the year beginning on August 1st, before the Madison meeting, and ending on August 1st, 1894. The small attendance at Madison, owing to the World's Fair, as noticed in the last volume of Proceedings, and the general financial depression of the past year, have had their effect on the cash account, but there is still a cash balance on hand; and it is a sign of progress that larger grants for the encouragement of research were made at the Brooklyn meeting than ever before. It is with much satisfaction that I have turned over to the new Treasurer of the Association the securities in full of the two funds which for so many years

I have been saving and adding to, little by little, until there is now a good nucleus for a research fund.

Although the interest of the fund received from commutation of assessments by which a member is made a life member could have been used for current expenses during the life of any such member, the income derived from the commutation of living members has not been used for current expenses, but has been regarded as income from the permanent fund. In this way, and by depositing in the savings bank such other savings as I could make, I had the satisfaction of turning over to the Treasurer a total of $5851.79, and received from him the following receipt: —

Brooklyn, New York, Aug. 22, 1894.

Received of F. W. PUTNAM, Permanent Secretary of American Association for the Advancement of Science, Deposit Book of Cambridge (Mass.) Savings Bank, showing deposit of $137.31 of General Fund and $150.00 of Research Fund; and Treasurer's check on State Street Safe Deposit and Trust Co. (Boston), for $5564.48.

R. S. WOODWARD,
Treasurer, American Association for the Advancement of Science.

Since the Brooklyn meeting completed twenty-one years of continuous service as Permanent Secretary, I may be permitted to refer to a few statistics, showing the increase of the Association during that period.

In 1873 there were about 600 members on the roll; at the present time there are three times that number, notwithstanding the loss by death of 341 members during the 21 years.

In 1874 the Association was incorporated and the new constitution was adopted. The members were then grouped under the headings of Patrons, Members, Honorary Fellows, and Fellows. Life membership was also established, and a permanent fund was started from the commutations of members who became life members, the income of this fund to be used for the encouragement of research. This fund, as already stated, has now reached the sum of $5714.48, while small savings from time to time have amounted to $137.31. At the New York meeting, in 1887, the first grants were made from the income of the Research Fund; and up to the present time $2200 have been given for the encouragement of scientific research.

Three volumes of the Proceedings have been reprinted. A single number of the Memoirs has been printed by the special gift of Mrs. Elizabeth Thompson, the first patron of the Association.

Twenty-one years ago, the Association was divided into two sections; now there are nine.

At the Brooklyn meeting there was an expression of views on the part of members favorable to accepting the invitation to hold the meeting of 1895 in San Francisco, and a committee was appointed with power to call the meeting in that city, provided satisfactory arrangements could be made for transportation over the transcontinental routes. After considerable correspondence and several conferences it was decided to submit the matter to a special meeting

of the Council, which was called in New York on January 26, 1895. At this meeting it was decided that the expense of attending a meeting in San Francisco would be so great for a large majority of the members, owing to the lack of any considerable reduction from the regular rates of railroad fares, that there was little likelihood of a large attendance. The Council therefore voted that the meeting in San Francisco be postponed, with the understanding that the matter be further discussed at the coming meeting, when definite statements as to expense could be presented and considered. That a meeting should be held on the Pacific Coast in the near future, is unquestionably desirable; and a large membership should be added from the Pacific States.

At this meeting of the Council the following invitation to hold the next meeting in Springfield, Mass., was read and accepted:

City Library Association, Springfield, Mass.,
January 7, 1895.

F. W. PUTNAM,
PERMANENT SECRETARY OF THE AMERICAN ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE.

DEAR SIR:

I send you herewith the formal invitation to the Council of the American Association for the Advancement of Science to hold the next meeting of the Association in Springfield. I can assure you, and through you the Council, that if this invitation is accepted, the Association will have a hearty welcome from our citizens, and that every possible provision will be made for their accommodation.

Will you please give me early notice of the action of the Council. If the decision is favorable, we shall arrange at once for the appointment of our local committee, and shall be happy to confer with you in reference to the provision which should be made for the meeting.

Very truly yours,
WILLIAM RICE,
Chairman of Joint Committee.

Springfield, January 1, 1895.

TO THE COUNCIL OF THE AMERICAN ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE.

GENTLEMEN:

The undersigned being authorized to represent the organizations set opposite their names, or joining heartily with them in their individual capacity as citizens of Springfield, do hereby extend a cordial invitation to your honorable body to hold the next annual meeting of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE in the city of Springfield.

CHARLES L. LONG, Mayor of the City of Springfield.

JAMES T. ABBE, LEWIS C. HYDE, CHARLES HALL, W. O. DAY, and NEWRIE D. WINTER, of the Board of Trade.

JAMES A. RUMRILL, WILLIAM RICE, WILLIAM H. HAILE, SAMUEL BOWLES, and HENRY H. BOWMAN, of the City Library Association.

O. S. GREENLEAF, HENRY HALL BOSWORTH, and ADELAIDE H. TRASK, of Springfield Improvement Association.

JOHN C. BROOKS, BRADLEY GILMAN, ELIZA G. WHITING, JANE E. LAW, and EDWARD C. ROGERS, of the Union Relief Association.

WILLIAM S. SHURTLEFF, President of Connecticut Valley Historical Society.

W. W. COLBURN, President of Peabody Society.

THOMAS M. BALLIET, Superintendent of Public Schools.

FRED W. ATKINSON, Principal of High School.

LESLIE P. STRONG, Superintendent of Christian Industrial and Technical Institute.

DAVID ALLEN REED, President of School for Christian Workers.

S. H. LEE, President of French American College.

CHARLES H. BARROWS, President of Young Men's Christian Association Training School.

A. MORDECAI, Colonel of Ordnance Department, Commanding United States Armory.

MARIA L. OWEN, President of Springfield Botanical Society.

D. B. WESSON, A. H. OVERMAN.

MARSHALL CALKINS, EDWIN F. LYFORD, and WILLIAM ORR, Jr., Resident Members of the American Association for the Advancement of Science.

The experience of the past two years in relation to the uncertainty of the place of meeting of the Association has been so unsatisfactory that it suggests the desirability of making a change in the rules of the Association, so that the place of meeting can be decided upon at least two years in advance, and a waiting list of places be established. At the present time there are several cities desirous of receiving the Association. Among them are Buffalo, San Francisco, Staunton, Va., and Lexington, Va. Would it not be far more satisfactory to all concerned if there could be always on the list a number of places from which to select — with due respect to geographical distribution and other considerations — the places of meeting for two or three years in advance?

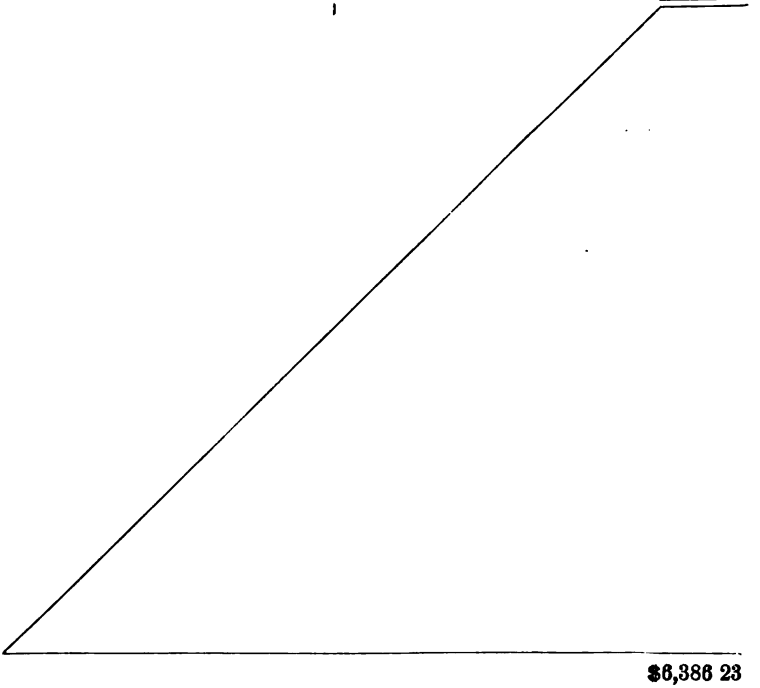
F. W. PUTNAM,
Permanent Secretary.

March 16, 1895.

F. W. PUTNAM, PERMANENT SECRETARY,

Dr. THE AMERICAN ASSOCIATION FOR

1893–94.		
To balance from last account		$1,875 46
Admission fees Madison meeting	$300 00	
Fellowship fees	72 00	
		372 00
Assessments previous to Madison meeting	885 00	
" Madison meeting	2,478 00	
" for Brooklyn meeting	387 00	
Associate fees Madison meeting	105 00	
		3,855 00
Sundry receipts	19 50	
Publications sold	61 02	
Received for binding	51 75	
Subscription to volume	1 50	
		133 77
Life members' commutations		150 00



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FOR THE

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FOR THE FORTY-THIRD MEETING

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AUGUST, 1894.

SALEM:
PUBLISHED BY THE PERMANENT SECRETARY.
MARCH, 1895.

PUBLICATIONS

FOR SALE BY THE

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